Some Aspects of Biology of Bivalves from Kakinada Bay, East Coast of India

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ABSTRACT
Biological aspects such as maturation, size at first maturity, spawning season, sex ratio, length – weight relationship, age and growth studies of *Perna viridis*, *Crassostrea madrasensis*, and *Meretrix casta* have been carried out during June 2013- May 2015 from Kakinada Bay. A scale of four stages of maturity i.e. maturing, matured, spent and recovery was noticed in the present study. The size at first maturity in females was reported at 7.2 cm, 7.2 cm, and 4 cm length, whereas in males it was reported at 7.2 cm, 8.7 cm, and 4 cm length for *P. viridis, C. madrasensis,* and *M. casta* respectively. These bivalves spawn throughout the year with peak spawning season during pre-monsoon in *P. viridis*, *C. madrasensis* and *M. casta*. Females were dominant in the catches of bivalves during the study period. The growth pattern in bivalves indicated that *P. viridis* and *C. madrasensis* showed negative allometric growth, while *M. casta* showed isometric growth. The growth parameters noted were $L\infty = 22.4$ cm, $K= 0.31$, $t_o = -0.34$ in *P. viridis*; $L\infty = 22.6$, $K = 0.40$, $t_o = -0.43$ in *C. madrasensis*; and $L\infty = 7.7$, $K = 0.20$, $t_o = -0.35$ in *M. casta*. The growth rate was high in young bivalves and decreased subsequently towards advancement of age.

Keywords: Biology, size at first maturity, spawning season, length-weight relationship, growth parameters.

INTRODUCTION

Edible marine mollusks, such as clams, mussels, oysters and various gastropods are vital sources of sea food and so have become an important socio-economic entity for coastal communities. Exploitation of bivalve plays an important role in the national economy of many countries (Vakily, 1992). The increasing demand for food production and the alarming decrease in some of the traditional finfish fisheries has readily supported to the development of commercial shellfish farming (Vakily, 1989). The average global production of marine bivalves for human consumption is more than 50 million tons per year during 2010-2015, which is about 14 % of the total marine production in the world (Wijsman *et al*., 2018). About 1100 species of bivalves have been reported from India and presently over 1,00,000 tons of bivalves were exploited from Indian waters (Sunil and Venkatesan 2017). About 70,705 tons of bivalves were landed in Kakinada Bay from 1996 – 2000 (Appukuttan *et al.,* 2002). In recent years a significant decline in the landings of the commercially important bivalves has been recorded which raises issues of management and conservation of the resources. The estimated total landings of bivalves in India were 12,979 tons (CMFRI, 2023). The estimated total bivalves landed from Kakinada Bay during 2011, 2013 and 2023 were <2000 tons only (Laxmilatha, 2015; CMFRI, 2023). Details on specific aspects of bivalve management, biology, aquaculture and their relations to economic, public and ecosystem health are of paramount importance, but are at present lacking. The importance of maintaining healthy molluscan populations and the type of information needed to sustain these structural and functional resources cannot be over emphasized (Sunil and Venkatesan 2017).

Studies on reproductive biology of bivalves are essential to determine the reproductive potential of a population. The analysis of length weight data constitutes an essential part of investigation on any fisheries stock, the length weight relationship also required for setting up yield equations and in comparing life histories of species in different regions (Broom, 1982; Beverton, 1957; Ricker, 1973; Stergiou and Moutopoulos, 2001; Park and Oh, 2002; Ansa and Allison, 2008; Ganapathi and Gangadhara, 2015). Age and growth studies provide data for effective bivalve fishery management and also for rational exploitation. These findings will provide basic information on the biology of the bivalves for estimation of biomass, stock management, conservation and planning for sustainable aquaculture (Munawar *et al*., 2017). Relatively very few studies on biology have been carried out on bivalves from Kakinada Bay, except Narasimham, 1980 and 1987. Due to the paucity of information on biology of marine bivalves, the present study aimed to obtain detailed information on maturation, size at first maturity, spawning season, sex ratio, length – weight relationships, age and growth studies of *Perna viridis* (Linnaeus, 1758), *Crassostrea madrasensis* (Preston, 1916) and *Meretrix casta* (Gmelin, 1791) from Kakinada Bay.

MATERIALS AND METHODS

Collection of Bivalves:

The marine bivalves, *P. viridis* (1030 specimens with a shell length between 1.8 and 18.0 cm; weight between 3.0 and 450 g), *C. madrasensis* (1035 specimens with a shell length between 2.0 and 22.0 cm; weight between 5.0 and 738 g), and *M. casta* (852 specimens with a shell length between 2.0 and 6.8 cm; weight between 4 and 120 g) were collected

randomly on every month from Kakinada Bay, near Chollangi village in the stretches of Coringa mangroves (Fig.1) by hand picking at low tide (Approximately 1 m depth), using motor boat during June 2013 - May 2015. Bivalves were packed in wet gunny bag and transferred to the wet laboratory of Department of Marine Living Resources of Andhra University and placed in seawater with suitable salinity (between 20 and 30 ppt) and allow them for depuration. Bivalves were cleaned off all epifauna and epiflora with a brush and washed. These bivalves (Fig.2) were identified based on standard taxonomic keys (Nayar and Mahadevan, 1974; Bouchet and Rocroi, 2010; Carter *et al*., 2011). The bivalves selected for these studies were available in plenty throughout the year.

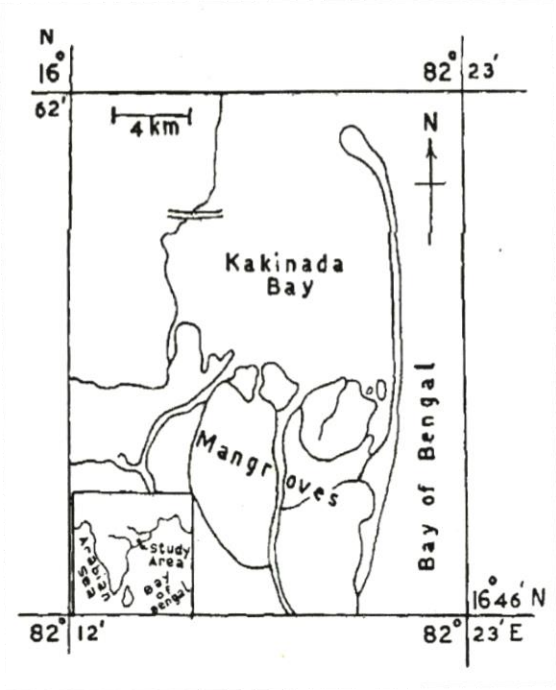


Fig.1: Study area Map

***A. Perna viridis* (Linnaeus, 1758)**

B. *Crassostrea madrasensis* (Preston, 1916)

***C. Meretrix casta* (Gmelin, 1791)**
Fig.2: Bivalves collected from study area

Reproductive Biology
Maturity of gonads was determined by external appearance like colour, size, area occupied by them on the body cavity and microscopic observations of ova and sperm (Narasimham, 1980). The size at first maturity was determined for males and females at that average size at which 50% of the population attains first maturity (Narasimham, 1980). For this study, matured males and females were examined and their percentage frequencies falling in different length groups were studied. Determination of spawning season was based on percentage occurrence of mature bivalves (West, 1990). The period, during which the percentage of occurrence of mature bivalves was high, it was considered as the spawning season. The sex was noted after open the shell based on external appearance of gonads and microscopic observations of ova and sperm. The ratios of male and female were calculated in relation to month.

Length-Weight relationship
The measurement of total length and weight of males and females of bivalves was taken in fresh condition, after removing excess moisture by blotting paper. The length-weight relationship was estimated by using the formula $W = aL^b$ (Le Cren, 1951).
Where W = weight of the bivalve in g.
L = Length of the bivalve in cm.
a = constant
b = exponent
For testing the difference between the regression slopes of males and females, regression analysis and Analysis of covariance (Snedecor and Cochran, 1967) were carried out for length-weight relationship of the four species respectively.

Age and Growth studies
The age and growth of four bivalves were estimated by applying the ELEFAN I (Electronic Length Frequency Analysis) method (Pauly and David, 1981) (FiSAT II Software package, version 1.2.2). For the estimation of age and growth, length of each specimen was recorded for two years. The month–wise length frequency data was analyzed by ELEFAN I module to get the $L\infty$, K and t_0. The values $L\infty$, K and t_0 thus obtained were fitted in the Von Bertalanffy growth equation (Von Bertalanffy, 1938) to get the growth per year. The growth model is
$L_t = L\infty\ (1 - e^{-k(t-to)})$.
Where,
L_t = length at age t,
$L\infty$ = asymptotic size to which the individual grows,
K = growth coefficient
t_o = age of the individual bivalve at zero size.

RESULTS AND DISCUSSION
A scale of four maturity stages i.e. maturing, matured, spent and recovery were reported in the present study on *P. viridis, C. madrasensis* and *M. casta.* It was also adopted to evaluate variations in the frequency of maturity stages more precisely and to determine the spawning period specifically. The present work was in agreement with earlier studies on bivalve maturity (Munawar *et al*., 2017; Narasimham, 1980; Narasimham, 1987; Rajapandian and Rajan, 1983; Sreenivasan *et al*., 1989; Rajagopal *et al*., 2000). On contrary to the present study five stages of sexual maturity was described in various bivalves by earlier authors (Erik Baqueiro *et al*., 2000; Suja and Muthaiah, 2007; Jintamas *et al*., 2009; Sandhya and Baban, 2009; Hadi *et al*., 2015). These variations may be attributed to species variation and geo-ecological conditions of the study area.
The size at first maturity in females was reported at 7.2 cm, 7.2 cm and 4.0 cm for *P. viridis, C. madrasensis* and *M. casta* respectively (Fig. 3-5), but minimum size at which ripe gonads were noticed as 3.0 cm, 4.4 cm and 2.9 cm in *P. viridis, C. madrasensis* and *M. casta* respectively, which were similar to that of the works done on bivalves in other areas by

various authors (Vakily, 1989; Narasimham, 1980; Narasimham, 1987; Siddall, 1980; Jayabal and Kalyani, 1986; Sawant and Mohite, 2013). The minor variations may be attributed to environmental, geographical and species variety.

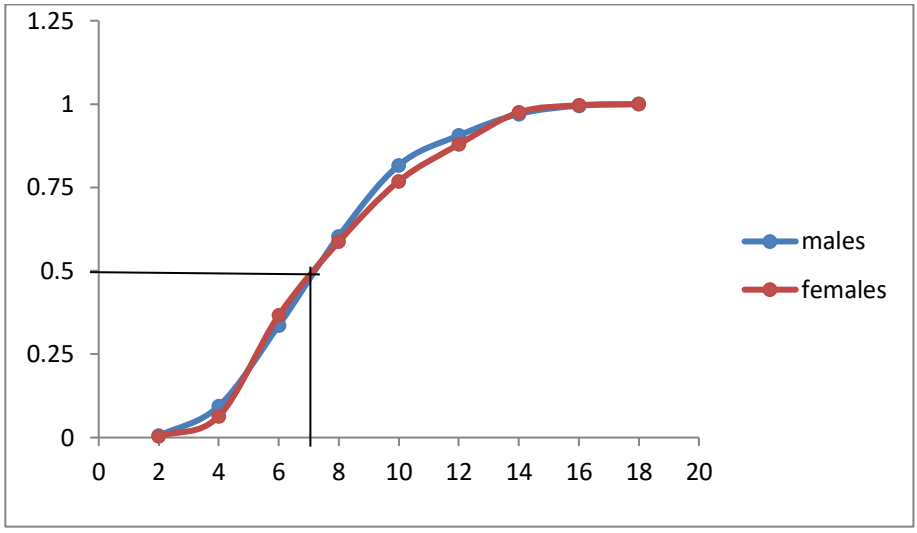


Fig.3: Size at first maturity in males and females of *P. viridis*

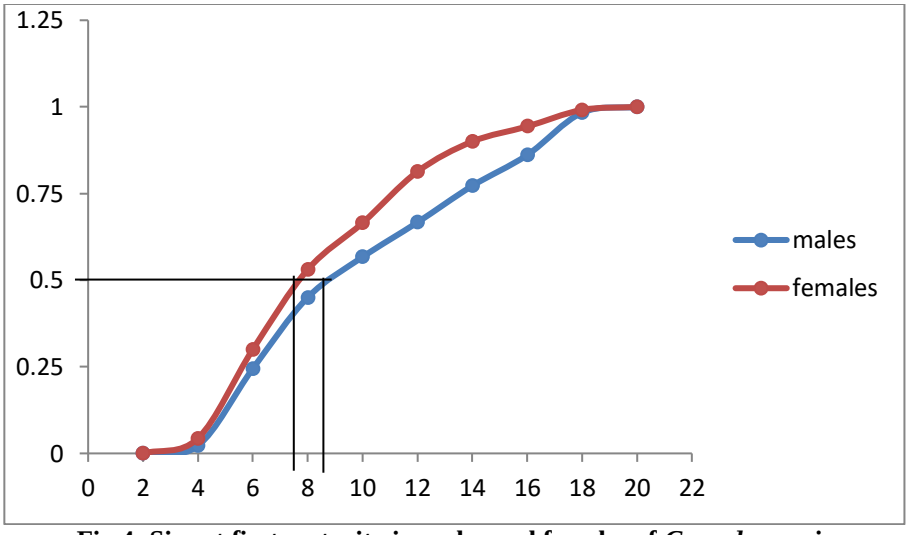


Fig.4: Size at first maturity in males and females of *C. madrasensis*

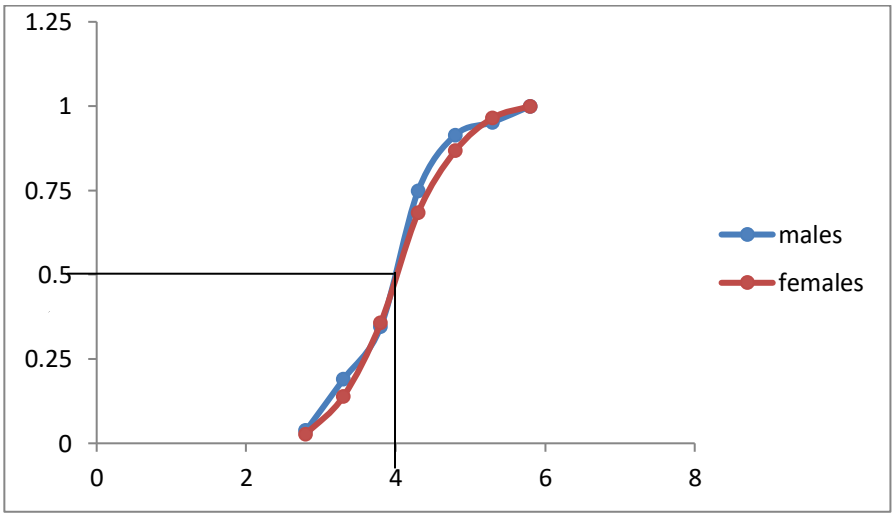


Fig.5: Size at first maturity in males and females of *M. casta*

The present study indicated that bivalves spawn throughout the year, but the peak spawning probably in pre monsoon in *P. viridis*, *C. madrasensis* and *M. casta* (Table 1-3). The variations may be attributed to favorable temperature and

abundance of their natural food. Similar results were also noticed in works done by earlier authors (Narasimham, 1980; Narasimham, 1987; Rajapandian and Rajan, 1983; Sreenivasan *et al*., 1989; Sandhya and Baban, 2009).

Table.1: Percentage frequency of maturity stages in *P. viridis* during June 2013- May 2015

Season	Maturing%		Matured%		Spent%		Recovery%	
	Males	Females	Males	Females	Males	Females	Males	Females
Monsoon-2013	25	16	56	62	19	14	-	7.5
Post monsoon-2013-14	47.5	56	12.5	20	16	10	24	14
Pre monsoon-2014	19	8	22	35	40	45	19	12
Monsoon-2014	40	40	33	40	27	10	-	10
Post monsoon-2014-15	49	46	19	26	15	10	17	18
Pre monsoon-2015	4	5	42	40	40	42	14	13

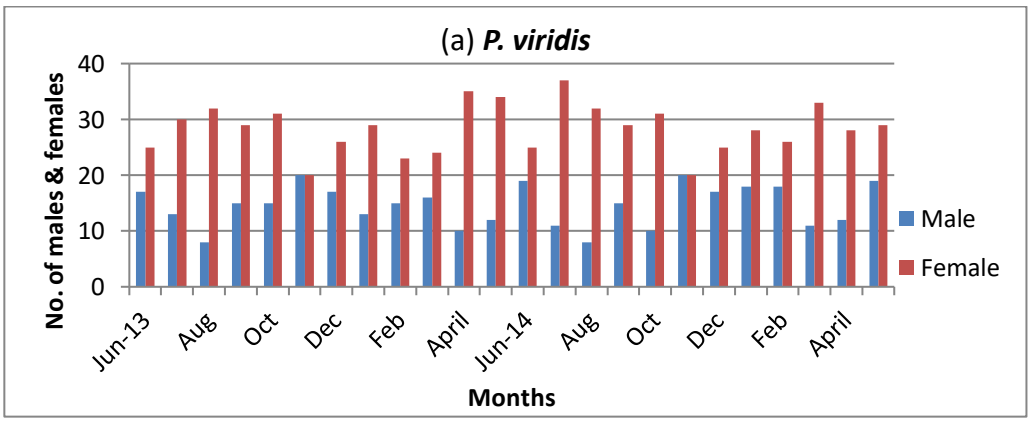
Table.2: Percentage frequency of maturity stages in *C. madrasensis* during June 2013- May2015

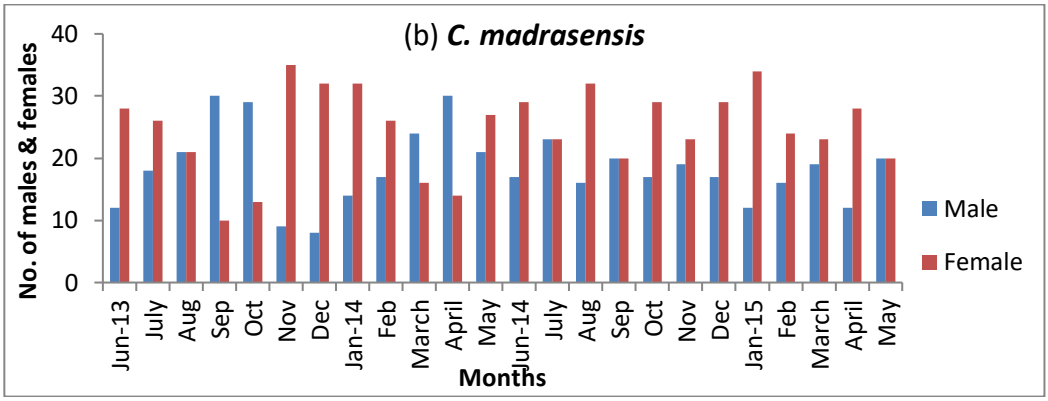
Season	Maturing%		Matured%		Spent%		Recovery%	
	Males	Females	Males	Females	Males	Females	Males	Females
Monsoon-2013	13	16	41	56	40	28	6	-
Post monsoon 2013-14	37	46	21	17	22	19	12	18
Pre monsoon 2014	29	36	58	59	7	5	6	-
Monsoon 2014	8	15	50	60	34	25	8	-
Post monsoon 2014-15	50	54	10	13	21	15	19	18
Pre monsoon 2015	36	42	64	54	-	4	-	-

Table.3: Percentage frequency of maturity stages in *M. casta* during June 2013- May 2015

Season	Maturing%		Matured%		Spent%		Recovery%	
	Males	Females	Males	Females	Males	Females	Males	Females
Monsoon 2013	41	50	59	50	-	-	-	-
Post monsoon 2013-14	27	16	24	27	35	32	14	25
Pre monsoon 2014	27	31	30	31	30	25	13	13
Monsoon 2014	41	55	59	37	-	-	-	8
Post monsoon 2014-15	28	15	24	23	35	40	13	22
Pre monsoon 2015	27	41	30	31	30	15	13	13

The sex ratio for male to female during the study period was 1: 2.18 in *P. viridis*; 1:1.42 in *C. madrasensis*, *and* 1:1.53 in *M. casta* (Fig.6). Females dominated the catches at Kakinada Bay. It was evident that both the sexes were not equally distributed and hence can be inferred that there was a significant deviation in the sex ratio from the expected 1:1 ratio in the catches during the study period at Kakinada Bay. Female dominance was also noticed in earlier works on bivalves (Narasimham, 1987; Rao, 1956). On contrary, male dominance was also noticed in some bivalves (Rajapandian and Rajan, 1983; Hadi *et al*., 2015). These variations may be attributed to geographical, environmental, species variations and long life span of a particular sex.





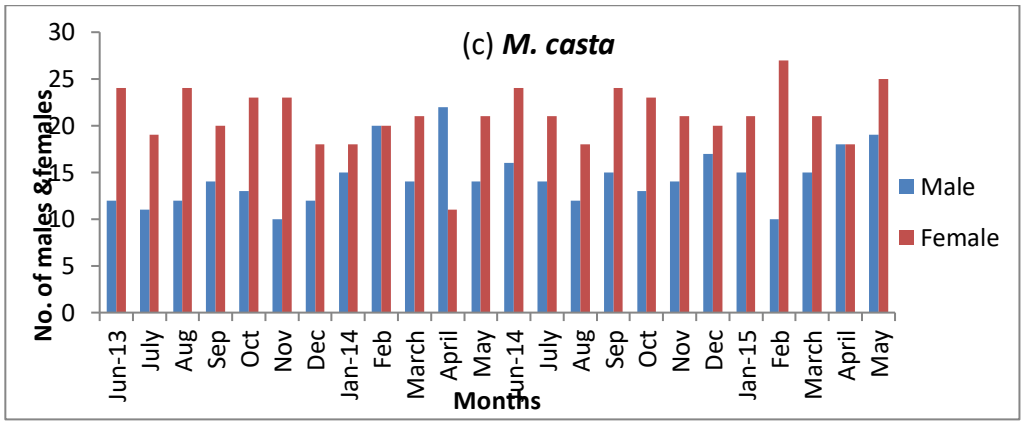


Fig.6: Sex ratio of bivalves

The scattered diagram of observed weight against length of all the three bivalves revealed a curve-linear relation between the two variables for both the sexes (Fig.7-9). Estimated constant 'a' and exponent 'b' in the linear form for pooled data in the present study were given as $W = 0.0000000877816L^{2.60039}$ (r = 0.97) for *P. viridis*, $W = 0.000000249362L^{2.46344}$ (r=0.91) for *C. madrasensis*, and $W = 0.000001071L^{2.90306}$ (r = 0.93) for *M. casta*. The growth co-efficient 'b' may range from 2 to 4 (Koutrakis and Tsikliras, 2003). The growth co-efficient 'b' generally lies between 2.5 and 3.5 and the relation is said to be isometric when it equals to 3 (Carlander, 1977). In the present study the growth co-efficient 'b' was 2.6 in *P. viridis*; 2.5 in *C. madrasensis*; and 2.9 in *M. casta.* The values of 'b' in the current study demonstrated that *P. viridis* and *C. madrasensis* showed negative allometric growth, while *M. casta* showed isometric growth, as mentioned by Koutrakis and Tsikliras (Koutrakis and Tsikliras, 2003). Negative allometric growth was also reported in earlier studies in various bivalves (Ansa and Allison 2008; Narasimham, K.A; Parulekar *et al*., 1982; Gaspar *et al*., 2001; Rupam *et al*., 2005; Al-Barwani *et al*., 2004; Mane and Sundaram, 2014). The isometric growth pattern was also noticed in bivalves by earlier authors (Ansa and Allison, 2008; Gaspar *et al*., 2001; Laxmilatha *et al*., 2013). These variations may be attributed to ecological conditions, food availability and stress in the study area.

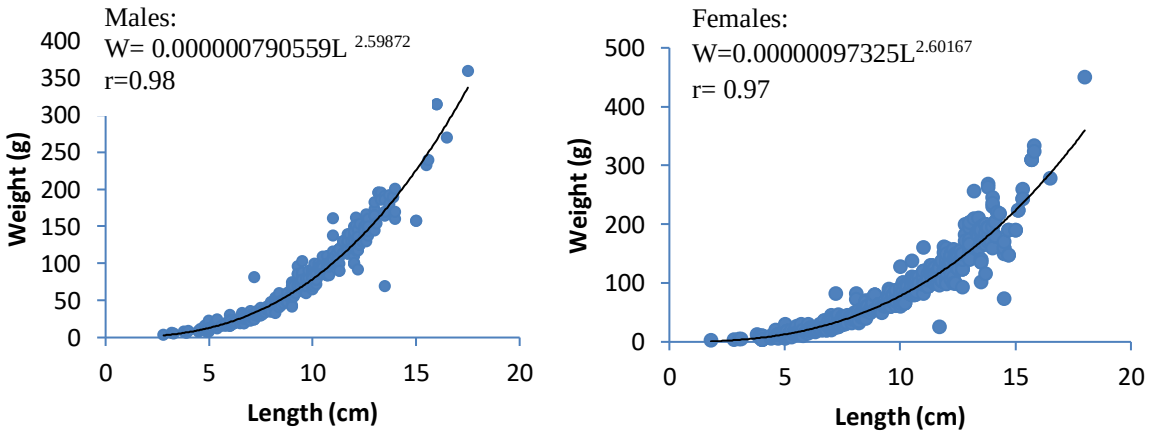


Fig.7: Scattered diagram showing length-weight relationship between males and females of *P. viridis*

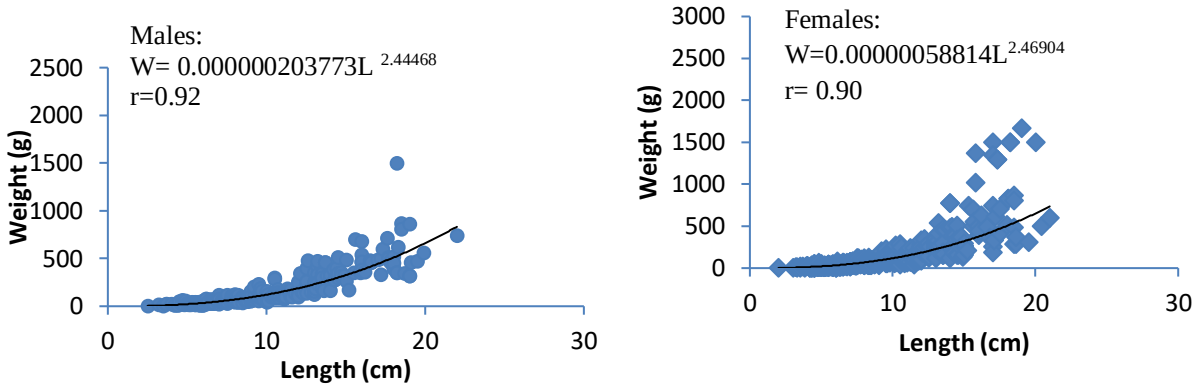


Fig.8: Scattered diagram showing length-weight relationship between males and females of *C. madrasensis*

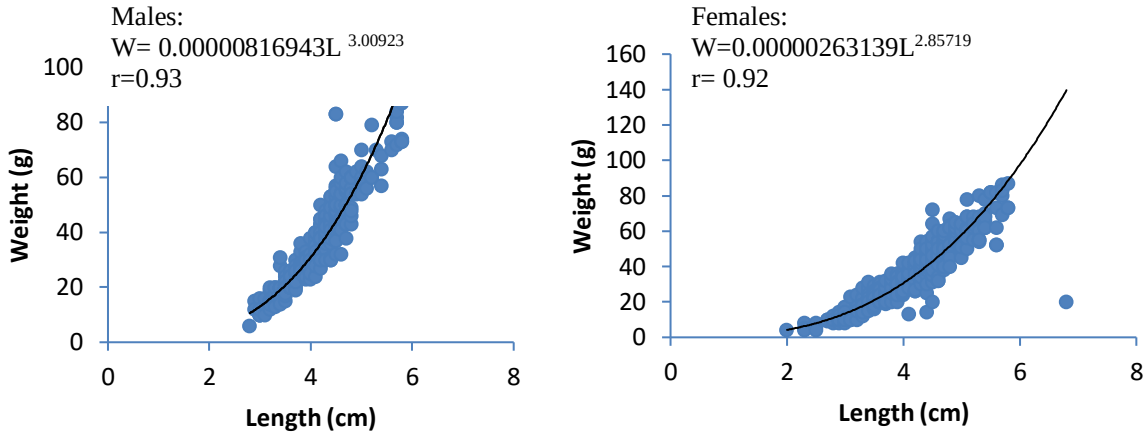
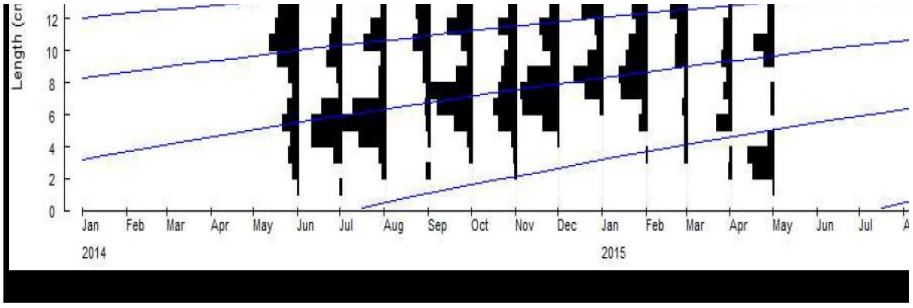


Fig.9: Scattered diagram showing length-weight relationship between males and females of *M. casta*

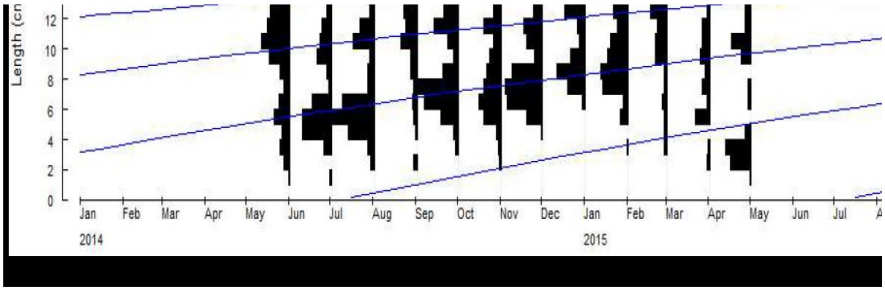
The Von Bertalanffy growth function, a predictable explanation for growth rate of clams (Vakily, 1992; Caddy, 1989). Yin *et al*., 2003 found that the growth curve in bivalves was sigmoid in shape and the Von Bertalanffy growth model was able to provide a perfect fit in relation to length frequency. Furthermore, the sigmoid growth curves were observed in bivalves (Tsoularis and Wallace 2002; Lei and Zhang 2004). Assessment of bivalve growth rate by measuring the shell length increase is acceptable and is evident that the growth rate is faster in early ages than in the later stages (Hickman, 1979; Frechette and Grant 1991; Seed and Suchanek 1992; Cheung, 1993; Alvarado and Castilla 1996; Dahlhoff and Menge 1996; Mc Quaid and Lindsay 2000; Alan *et al*., 2004). The present study supports this statement strongly and exhibited a decrease in growth rate from end of first year and high growth rate was noticed in early months in all four bivalves.

The growth parameters ($L\infty$, K, t_o) are helpful in comparing the growth rates between and within species inhabiting different habitats. In the present study the growth parameters noted were $L\infty$ = 22.4 cm, K= 0.31, t_o = -0.34 in *P. viridis*; $L\infty$ = 22.6, K = 0.40, t_o = -0.43 in *C. madrasensis*; and $L\infty$ = 7.7, K= 0.20, t_o = -0.35 in *M. casta* (Fig.10) which were more or less similar in various other bivalves (Broom, 1982; Narasimham, 1980; Chatterji *et al*., 1984; Syda Rao, 1988; Kamal and Khan 1988; Nurul and Zafar, 2008; Jayawickrema and Wijeyaratne 2009). The annual growth rate in the present study reported was 7.6 cm, 9.9 cm, and 1.8 cm in *P. viridis*, *C. madrasensis*, and *M. casta* respectively. The ELEFAN method confirmed the longevity to be 60, 72, and 72 months in *P. viridis*, *C. madrasensis*, and *M. casta* respectively (Fig.11). In the current study the growth parameters of three bivalves showed almost similarities with the results of earlier authors (Narasimham, 1980; Carlander, 1977; Chatterji *et al*., 1984; Syda Rao, 1988; Kamal and Khan 1988; Nurul and Zafar, 2008; Qasim, 1977; Narasimham, 1988a).



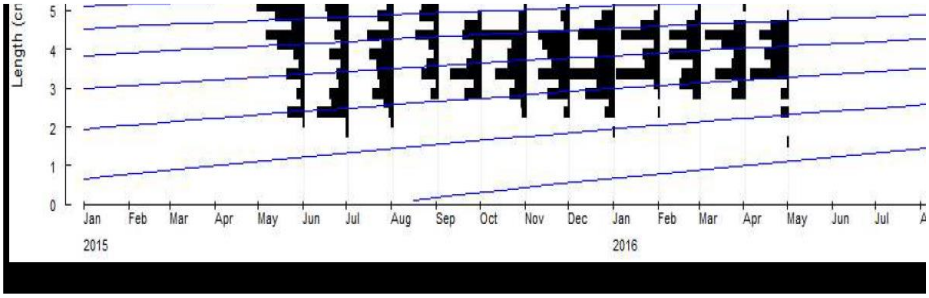
$L\infty$ = 22.43 K = 0.310 Score = 0.414

(a) P. viridis



L∞ = 22.58 K = 0.430 Score = 0.414

(b) *C. madrasensis*



L ∞ = 7.7 K = 0.22 Score= 0.2

(c) *M. casta*

Fig.10: Estimate of L∞ of bivalves from Kakinada Bay

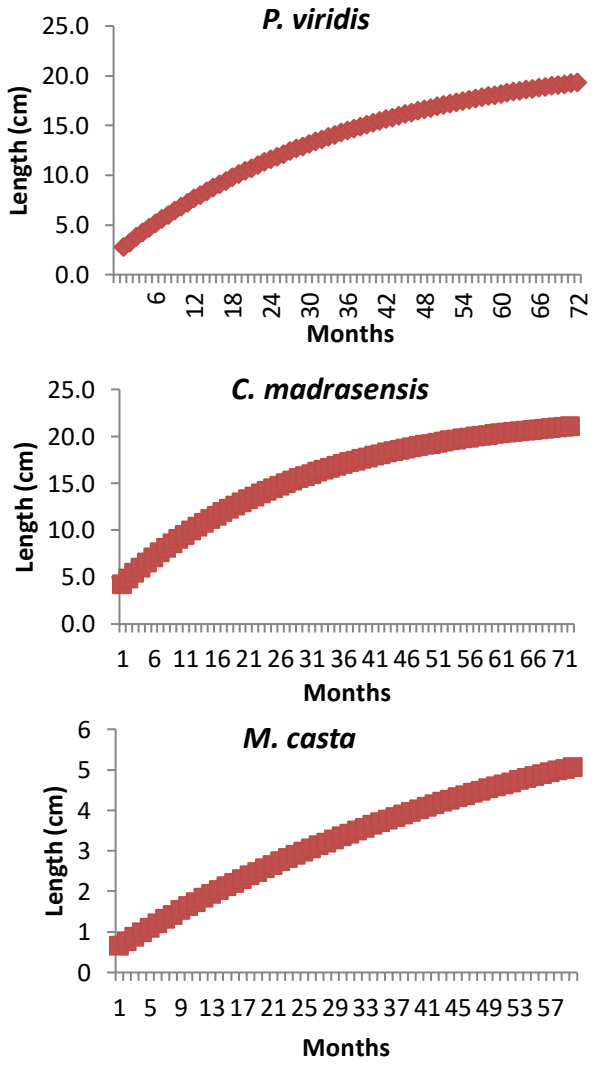


Fig.11: Growth curves of bivalves from Kakinada Bay

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