J. mar. biol. Ass. India, 1988, 30 (1 & 2) : 137-150

BIOLOGY OF THE BLOOD CLAM *ANADARA GRANOSA* (LINNAEUS) IN KAKINADA BAY

K. A. NARASIMHAM*

Central Marine Fisheries Research Institute, Cochin-682 031

ABSTRACT

A. Granosa spawns throughout the year and the major spawning months vary between years. There can be 2-4 reproductive cycles in a year. Males attain first maturity at 20 mm and females at 24 mm length. The male, female ratio during different months, years and also in different length groups is 1 : 1. The monthly average condition index (CI) based on the percentage of wet flesh weight in total weight varies from 15.1 to 23.1 and the same expressed as percentage of dry flesh weight in wet flesh weight ranges from 17.2 to 24.2. The trends in the values obtained by these two methods are comparable. The CI does not vary in relation to length. The infestation of *A. granosa* by the pea crab *Pinnotheres alcocki* varies from nil to 46% during different months (average 10.8%). In the crab-infested clams there is no damage to the organs of the host. The CI is low in 41.1% of the crab-infested samples when compared to the CI obtained in uninfested clams. The estimated parameters of the von Bertalanffy growth equation are L_∞ =73.4 mm, K = 0.5816/year and t_0 = —0.4088 yr. *A. granosa* attains 41.1, 55.3 and 66.3 mm on completion of 1,2 and 3 years respectively. Various morphometric and length-weight relationships are studied.

INTRODUCTION

THE BLOOD CLAM *Anadara granosa* is of considerable importance in the molluscan fisheries of the Kakinada Bay (Narasimham, 1973). The earlier works on aspects of biology of this species are by Narasimham (1969) from the Kakinada Bay and from Malaysia by Pathansali (1966) and Broom (1982, 1983).

I am thankful to Dr. E. G. Silas, former Director, Central Marine Fisheries Research Institute for encouragement and to Shri S. Mahadevan, CMFR Institute for going through the manuscript and suggesting improvements.

MATERIAL AND METHODS

To study spawning, sex ratio and condition index (based on wet flesh weight) fornightly samples consisting about 50 clams were collected from the fishermen catches during 1978-80 ; in 1981 the samples comprised about 25 specimens. The gonad smears of 3840 clams and histological preparations of 360 clams were examined. Standard histological techniques were followed to cut 7-10 μm thick gonad sections and stained with Delafield's haematoxylin and eosin. Ropes (1968) was followed in the categorisation of the maturity stages except that his 'early active' and 'late active' phases were clubbed under the maturing stage. Length at first maturity was studied by examining the gonad sections of 178 clams measuring 13.1-29.0 mm length and collected in April 1979 when there was a major spawning. The test of variance of homogeneity (Snedecor and Cochran 1967) was applied to test the significance of differences in the proportion of males. By Chi-square test it was ascertained whether the observed montly sex ratio differed from the theoritical 1 : 1. The condition index

**Present address* : Tuticorin Research Centre of CMFRI, 90, North Beach Road, Tuticorin.

(CI) was calculated as (*a*) percentage of wet flesh weight in total weight and (*b*) as percentage of dry flesh weight in wet flesh weight. To study the CI based on the latter method, the flesh of 20 specimens was dried in hot air oven at 80°C ± 1°C for 48 h, at fortnightly intervals. The CI in relation to length was studied in 152 clams measuring 21-60 mm and collected in September 1979 when there was no spawning. When pea crabs were present their weight was excluded in the calculation of CI. Age and growth was studied by growing 65 clams of the length range 4 to 65.8 mm in 50 cm×50 cm×15 cm dealwood boxes; each box was divided into 9 compartments. Each compartment was filled with sediment obtained from the clam bed, a measured clam introduced in it and the box was placed in the clam bed. Further details are given by Narasimham (1983). Length frequency study was made based on fortnightly samples obtained from the fishermen catches during 1978-81. The relationship between length and other body measurements was studied by fitting the regression equation of the type Y=a+bX; where required logarithmic transformation was applied. All linear measurements were taken to the nearest 0.1 mm with a vernier calipers and weight data to the nearest mg in electrical balance.

Spawning

The colour of the ovary varies from orange red to pale orange and that of testis from white to greyish white in different maturity stages. Based on the gonad colour, the sex can be easily distinguished.

January-February 1978: In January 22% and in February 10% of the clams were in partially spawned stage (Pl. I D, Pl. II D) while 63% and 86% were spent (Pl. I E, Pl. II E) with flabby gonads during these two months respectively (Fig. 1). The high percentage of spent clams in February indicates that the reproductive cycle, which appears to have been initiated prior to January, 1978 was completed by February.

March-June 1978: In March 32% and in April 25% were maturing (Pl I A, Pl. II A) with concurrent reduction in spent clams (Fig. 1). In March, while only 17% were in partially spawned stage, by April their number reached a peak (51%) and showed marginal reduction in May and June. These changes read with the absence of maturing clams in May-June and the dominance of spent clams in these two months indicate the completion of yet another reproductive cycle.

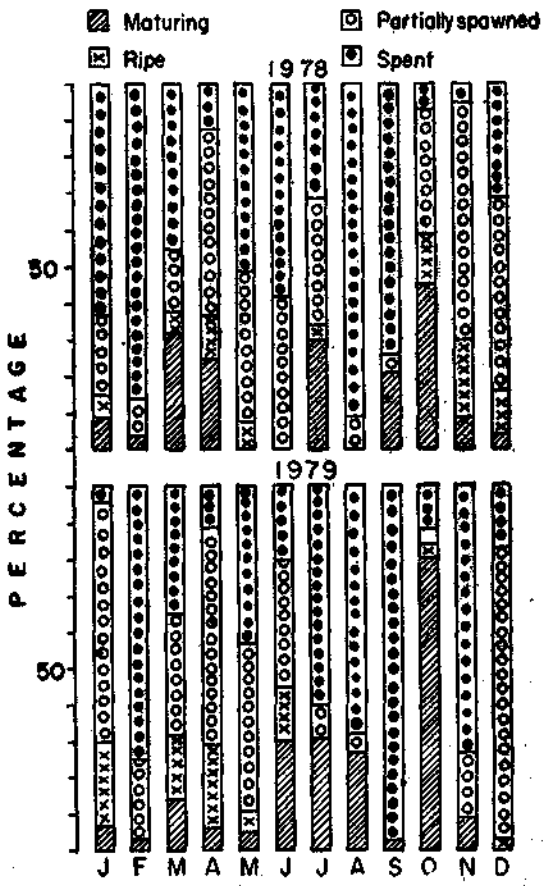

FIG. 1. Monthly percentages of different maturity stages in *A. granosa* during 1978 and 1979.

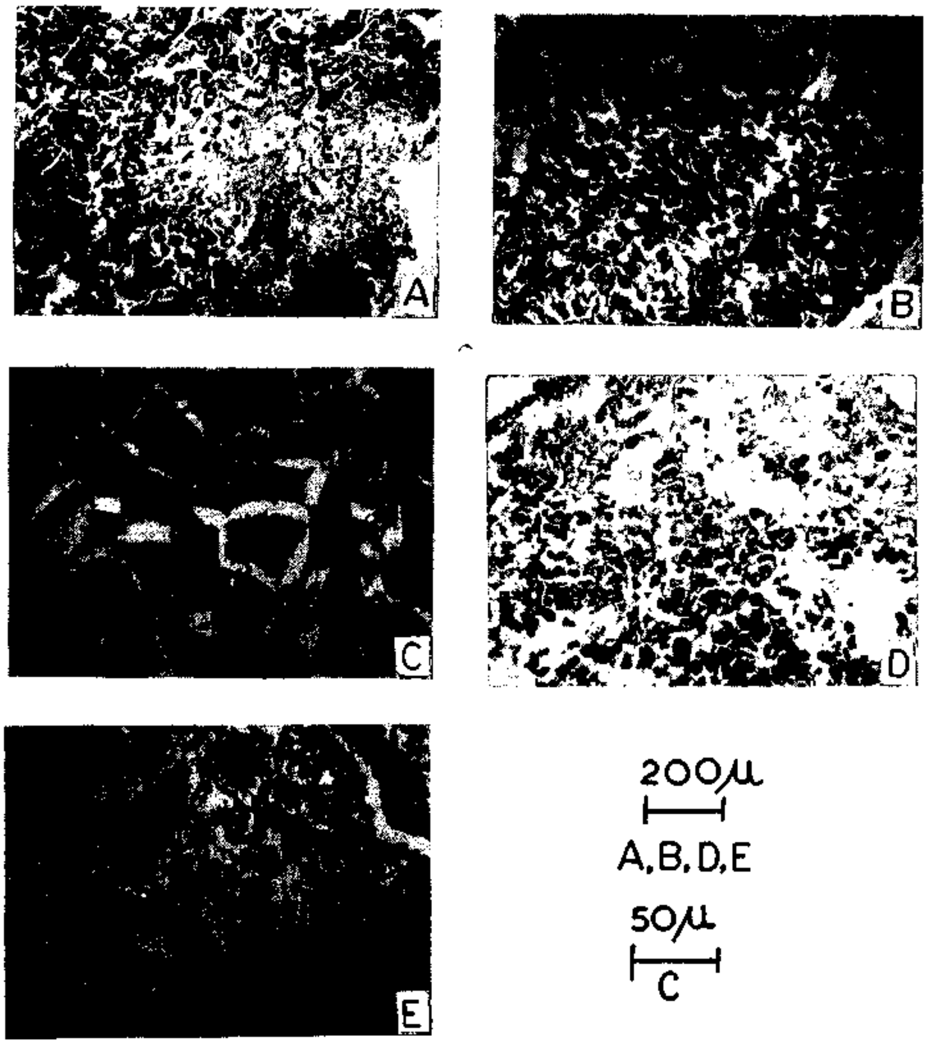

PLATE I. Female *Anadara granosa* : A. Maturing stage showing developing oocytes of various sizes, B. Ripe stage with densely packed ova ; some ova appear free in the enlarged follicles, C. Ripe stage at higher magnification. The ripe ova are polygonal in shapes, diameter ranges from 49-61 μm and the nuclei measure 22-33 μm, D. Partially spawned stage with some ripe ova in some follicles while other follicles are empty and E. Spent stage with residual ova undergoing cytolysis.

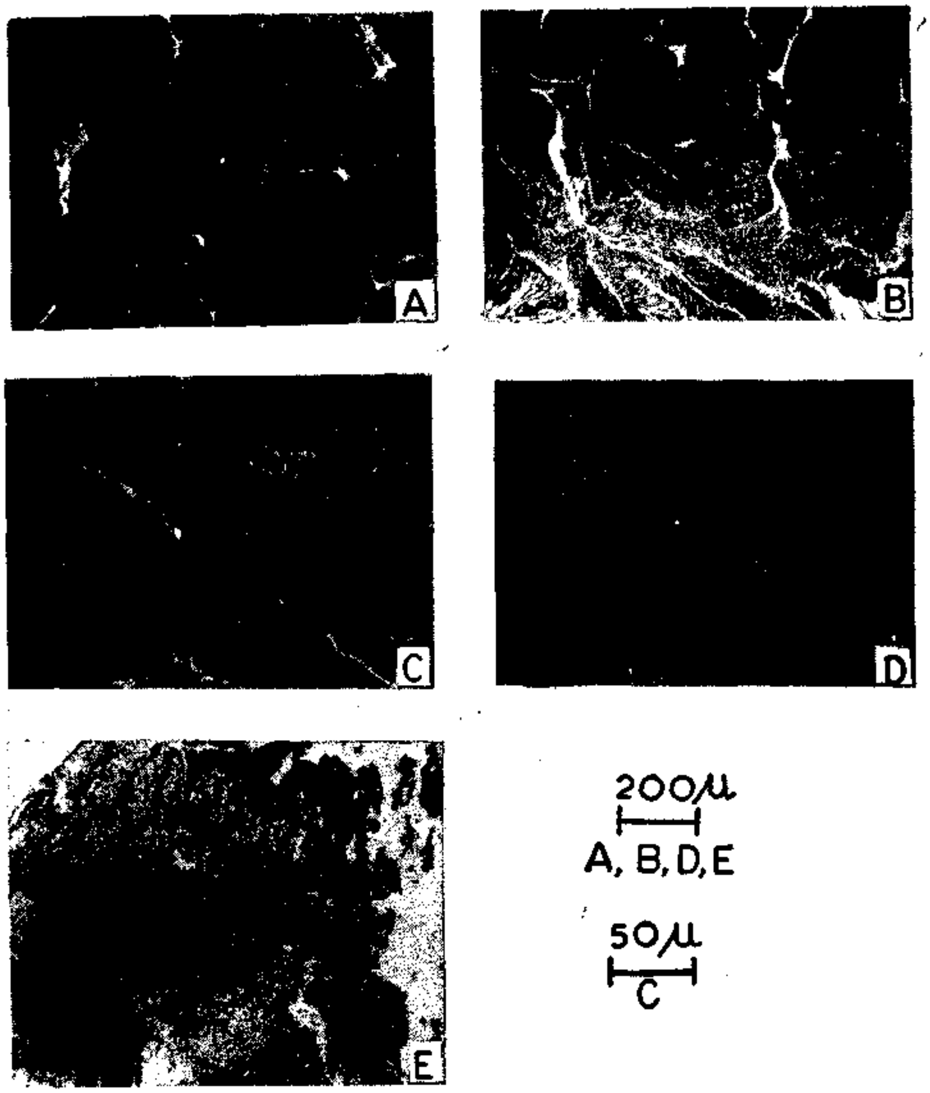

PLATE II. Male *Anadara granosa* : A. Maturing stage showing many developing follicles, B. Ripe stage showing many follicles densely packed with spermatozoa, C. Ripe follicle at higher magnification. Mature sperms are arranged in radial streaks with tails towards the centre of the follicle, D. Partially spawned stage with moderate quantity of spermatozoa in some follicles while others are mostly empty and E. Spent stage with many empty follicles and residual spermatozoa.

July-August 1978 : In July, while there was a reduction in the number of spent clams, 30% were maturing, few were ripe (Pl. I B, C ; Pl. II B, C and 35) were partially spawned (Fig. 1). By August regression of the gonad was observed resulting in 91% of the clams passing into the spent stage. This points to an abortive cycle with little spawning aking place.

September 1978 - *February* 1979 : Maturation was initiated in September and by October, 45% of the clams were in maturing stage concurrent with a decline in the number of spent clams from 74% to 7% in these two months (Fig. 1). The number of maturing clams was low at 3-9% during November 1978-February 1979. In September there was partial emission of gametes in 5% of clams ; the number of partially spawned clams increased to 34% by October and majority were in this state in the following three months indicating a major spawning in these 3 months. In December-January the partially spawned clams had flabby gonads as most of the gametes were released. By February spawning was completed and majority (75%) passed into the spent stage.

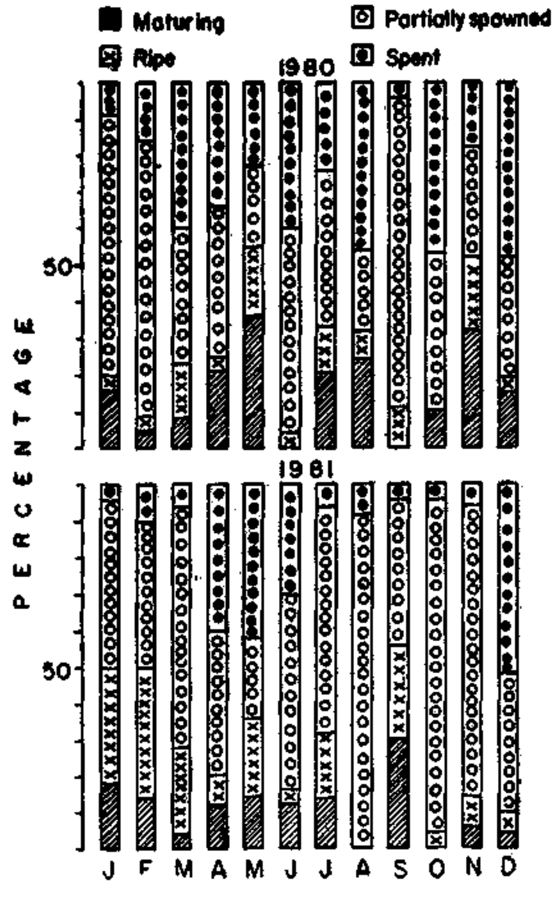

FIG. 2. Monthly percentages of different maturity stges in *A. granosa* during 1980 and 1981.

March 1979 - *December* 1981 : Reference to Figs. 1 and 2 show that there were major spawnings during April-May 1979, December 1979-February 1980, June 1980, September 1980, January 1981, March 1981, July-August 1981 and October-November 1981.

Remarks : It is clear from the four year study that in *A. granosa* individuals in all the four maturity stages occur in several months, ranging from 6 to 10 months during different years. These and the occurrence of partially spawned clams in all the months in different years (except September, 1979) lead to the conclusion that this species spawns throughout the year. It is also clear that there can be 2-4 reproductive cycles in a year and that their duration can vary considerably between years.

LENGTH AT FIRST MATURITY

Gonads were not developed in clams belonging to 14 and 16 mm length groups (Table 1). In the next length group gonad did not develop in 3 clams and the remaining 7 were maturing males. In the 20 mm group, 62.5% of the males were mature. From 22 mm group the percentage of mature males was high (over 80%) and it became cent percent in 28 mm group. Partially spawned male clams were first observed in 20 mm group and spent clams in 24 mm group. Hence 20 mm was taken as the length at first maturity in males.

TABLE 1. *Percentages of different maturity stages in length groups in* A. granosa

Length mm	Sex	N	Maturing	Ripe	Partially spawned	Spent
14	Indt	10	—	—	—	—
16	Indt	8	—	—	—	—
18	Indt	3	—	—	—	—
	Male	7	100.0	—	—	—
	Female	—	—	—	—	—
20	Indt	2	—	—	—	—
	Male	16	37.5	50.0	12.5	—
	Female	—	—	—	—	—
22	Male	14	14.3	28.6	57.1	—
	Female	3	66.7	33.3	—	—
24	Male	26	19.2	26.9	46.2	7.7
	Female	5	40.0	60.0	—	—
26	Male	31	6.5	19.4	64.5	9.7
	Female	7	14.3	14.3	42.9	28.6
28	Male	28	—	14.3	71.4	14.3
	Female	18	5.6	22.2	55.6	16.7

Indt. = Indeterminates

The females were first observed in the 22 mm group and majority of them were in maturing stage (Table 1). In the 24 mm group, 60% of females were mature and in 28 mm group their number increased to 94.4%. Majority of females (65.4%) were in partially spawned stage and a few were in spent condition in 26 mm group. The length at first maturity in females was taken as 24 mm.

SEX RATIO

The data on the monthly sex ratio in different years (Fig. 3) show that in most months the number of females exceeded that of males. The results of the test of variance for homogenity (Table 2) revealed that at 5% probability level, the Chi-square values during different years are not significant. It was next ascertained whether the observed ratio in each month showed significant difference from the theoretical 1 : 1 ratio. The Chi-square values showed that at 5% probability level there was no significant departure from the expected 1 : 1 ratio in any of the months. On annual basis, the ratio of males to females was 1 : 1.02 in 1978, 1 : 1.06 in 1979, 1 : 1.19 in 1980 and 1 : 1.09 in 1981 and the sex ration did not differ significantly from 1 : 1 at 5% during different years.

TABLE 2. *Test of homogeneity* (x^2) *for proportion of males in monthly of* A. granosa

Year	d f	x^2	Significance at 5 %
1978	11	3.136	Not significant
1979	11	4.840	,,
1980	11	7.807	,,
1981	11	6.481	,,

The data on sex ratio in relation to length are shown in Fig. 4. In 1978, the males were dominant in the 22 to 38 mm groups. Females

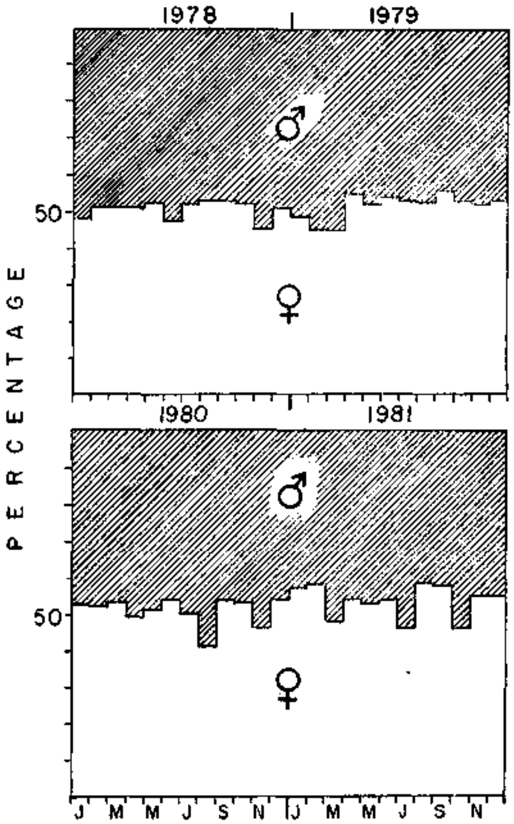

FIG. 3. Monthly sex ratio during 1978-81 in *A. granosa*.

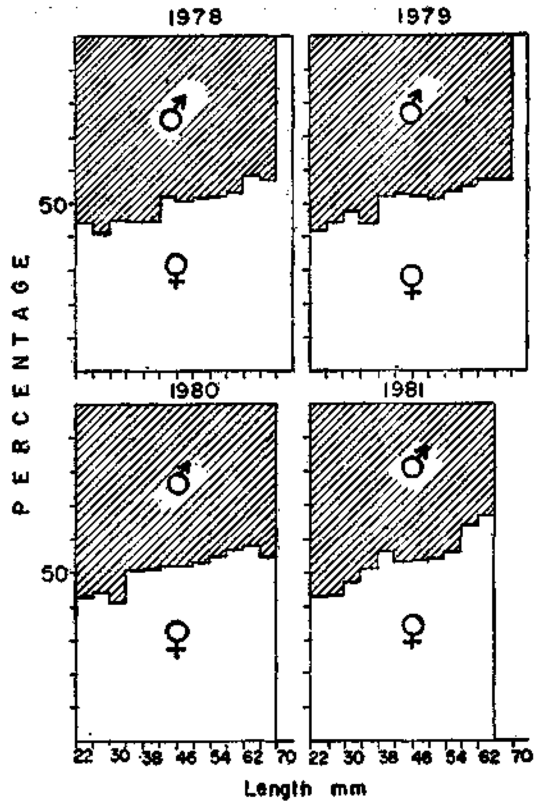

FIG. 4. Sex ratio in different length groups during 1978-81 in *A. granosa*.

predominated in the 42-66 mm groups while all were females in the 70 mm group. In the remaining three years in general, males outnumbered females in the first 3-4 length groups, females dominated in the rest of the length groups and at 70 mm all were females. Thus the trend in the distribution of sexes in different length groups is more or less same during different years. The Chi-square test showed that there was no significant departure from the excepted 1 : 1 ratio in any of the length groups except the 70 mm group in 1978 when the number of clams examined was below 5 in this length group. It is concluded from the above study that the samples were drawn from a population in which the male : female ration is 1 : 1.

CONDITION INDEX (CI)

Condition index based on dry and wet flesh weights : The values of average monthly condition index (CI) based on dry flesh weight varied from 17.2 in May 1980 to 24.2 in September 1979 (Fig. 5) with an average of 20.2 ; those based on the wet flesh weight ranged from 15.1 in December 1981 to 23.1 in September 1979 with an average of 19.1 (Fig. 5). The values of monthly average CI during 1978-80 based on the above two methods show that the trends in the fluctuations of CI obtained by those two methods are comparable. A plot of the average values of CI obtained by dry flesh weight method (Y) against those obtained by wet flesh weight method (X) for each month showed linear relationship which is described by the equation.

$$Y = 6.1292 + 0.7365X$$

and the correlation coefficient for the regression is 0.83 which is significant at 5%. Further studies of the CI were based on the wet flesh weight method.

Condition index in relation to length: The individual values of the CI in the sample varied from 16.0 to 26.2. However, the range of variation and means in each length group were more or less the same over the length range studied (Fig. 6). Analysis of variance (Table 3) showed that the CI is not significantly different at 5% between the length groups. This shows that the CI does not vary with growth.

TABLE 3. *Analysis of variance to study the significance of differences in condition index between different length groups in* A. granosa

Source of variation	d f	S.S.	M.S.	F
Between groups ..	7	49.81	7.1157	1.16
within groups ..	144	885.00	6.1458	
Total ..	151	934.81		

F (d = 7, 144) 5% = 2.07.

Seasonal changes in the condition index: During 1978 the CI was high in January, April-May, September and November; low in February, June, August, October and December (Fig. 5). In 1979 the CI was high during March-April, July and September and low during January-February, May-June, August and October-December. In the following year high values in the CI were observed during March-April, August and December and low values during January-February, May-July and October. In 1981 the CI attained peaks in January, July and October; it was low during April-June, August and November-December periods.

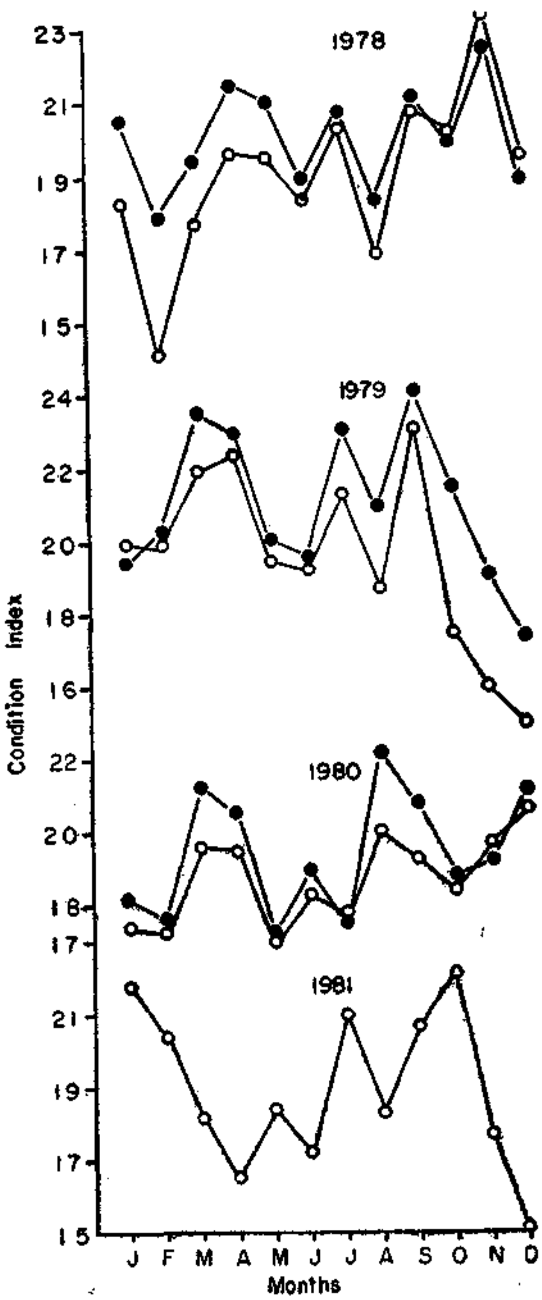

FIG. 5. Monthly average condition index based on dry flesh weight (solid circles) and wet flesh weight (open circles) in *A. granosa* during different years.

A study of the fluctuations in the CI in relation to the reproductive cycle (Fig. 1 and 2) showed

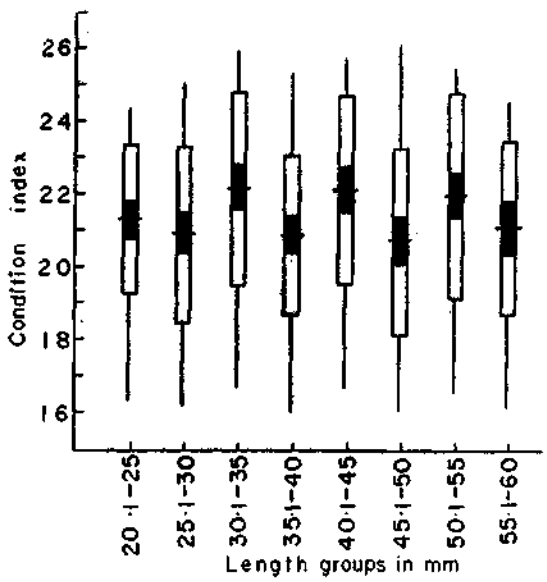

FIG. 6. Condition index in different length groups in *A. granosa*. The vertical, line shows the range small horizontal line the mean, the shaded and open boxes together one S.D. and the shaded box alone one S.E. on either side of mean.

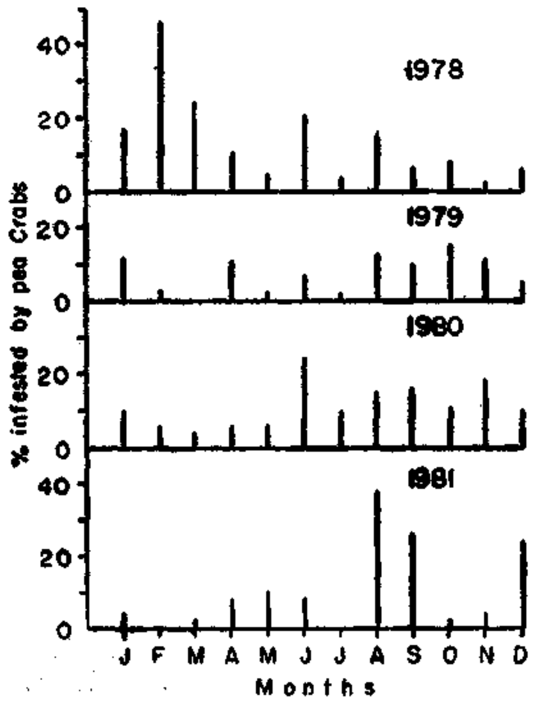

FIG. 7. Monthly percentage of *A. granosa* infested by the peacrab during 1978-81.

that the CI values were high when majority of the clams had moderately or well developed gonads (in maturing, ripe or partially spawned stages ; in the partially spawned stage bulk of the gametes not released) ; low CI values coincided with the months when majority of the clams had flabby or shrunken gonads and were in partially spawned or spent stages (in the former stage bulk of the gametes released). However, the high or low CI values cannot be explained on the above basis during January 1978, September-October 1978, June-July 1979, September-October 1979 and May 1980.

Pea-crab infestation and condition index : It was observed that some specimens of *A. granosa* were infested by the peacrab *Pinnotheres alcocki*. The crabs were found in the mantle cavity close to the gills on either side and there was no damage to the soft parts of the host. Except in March 1979, February and July 1981 the crabs were found in all the months (Fig. 7). The percentage of infested clams varied from nil to 46 in different months. The infestation was found to be 13.8% in 1978, 7.6% in 1979, 11.0% in 1980 and 10.7% in 1981. In all the four years together, the pea crab infestation was 10.8% of the clams. Multiple infestation was uncommon and of the 451 infested, only nine (2%) harboured two crabs each. There was no consistency in the monthly abundance in infested clams in different years (Fig. 7).

Of the 96 fortnightly samples of *A. granosa* examined, in 17 samples the percentage of infestation by the pea crab was 20 or more. Of these 17 samples, the average CI in the infested clams was lower than that in the un-infested ones in 12 samples whereas in the remaining five samples the reverse was true. The *t* test showed that out of these 17 samples only in 7 samples, the mean CI differed significantly at 5%. In all these 7 samples the CI of the infested clams was lower than that obtained in the uninfested clams. Thus in *A* *granosa* the CI is significantly low only in some instances of infestation by pea crabs.

Age and Growth

Growth of clams in boxes: The average growth rate of the clams varied from 0.2 to 3.28 mm/month depending upon the initial size (Table 4). Clams of 4.6 mm average length introduced in the box on 29.3.1979 have grown to 24.1 mm in 3 months, 33.4 mm in 6 months, 38.0 mm in 9 months and 43.9 mm in one year (Table 4). Similar growth data are available for other clams but their age when first introduced in the boxes is not known. It is known that the larvae of *A. granosa* settled in 21-22 days after fertilisation and the growth of the spat in the first 1-2 months was slow (Wong and Lim, 1985). By taking the larval life as 3 weeks and another 5 weeks for the spat to attain 4.6 mm it follows that from fertilisation *A. granosa* grows to 4.6 mm length in 2 months. The observed average lengths in the succeeding months are shown below and also as a broken line in Fig. 8. The

Age in months	2	3	4	5	6	7	8
Average length mm	4.6	11.6	19.2	24.1	28.0	30.4	33.4

two months old clams have grown to an average length of 38.1 mm in 11 months and 43.9 mm in 14 months. Clams measuring 30.4 mm average length (S. No. 6, Table 4) which can be considered as 7 months old have attained an average length of 49.2 mm in 19 months.

TABLE 4. *Quarterly average growth in length (mm) in* A. granosa *grown in boxes*

Length range		No.	29.3 1979	30.6 1979	28.9 1979	30.12 1979	29.3 1980
4.0—5.0	..	5	4.6	24.1	33.4	38.0	43.9
10.0—11.2	..	,,	10.7	26.7	34.5	38.6	44.1
15.0—15.8	..	,,	15.4	28.6	36.7	40.4	45.0
20.1—20.9	..	,,	20.6	32.5	39.6	42.6	46.9
25.2—26.4	..	,,	25.8	34.5	40.3	42.8	47.5
29.6—31.0	..	,,	30.4	37.9	43.2	45.6	49.2
35.0—35.7	..	,,	35.4	41.6	46.1	47.8	52.1
39.9—41.3	..	,,	40.7	45.7	49.7	51.0	54.2
44.8—45.5	..	,,	45.4	50.4	53.8	55.0	57.6
49.8—51.1	..	,,	50.4	54.5	56.7	57.9	60.6
55.0—56.2	..	,,	55.6	58.8	60.7	61.6	63.0
60.1—61.1	..	,,	60.7	63.2	64.0	64.7	67.2
64.5—65.8	..	,,	65.2	66.0	67.5	67.9	68.7

Length frequency distribution: Mode A at 22 mm in April 1978 was traced to 42 mm in 6 months by October 1978 (Fig. 9). Taking the age of the modal length at 22 mm in April as 4½ months on the basis of experimental study (*vide supra*) the age of the modal length at 42 mm in October was estimated at 10½ months. In the succeeding three months the modes were at 42 mm only. In February and March 1979 there were modes at 46 mm, in April 1979 at 50 mm in May 1979 at 46 mm, in June 1979 at 54 mm and at 50 mm in July and August 1979. Thus it was not possible to estimate the growth in these months based on the modal lengths. In 1979 there were modes at 30 mm in April, May and June (Fig. 9) and at 34 mm in July and August. Similarly there were modes at 42 mm in 3 months during October-December. In view of the above it was not possible to estimate the growth on the basis of modal progression during 1979. In 1980 there were modes at 30 mm in 5 months from February to June and also in November (Fig. 10). Mode B at 30 mm in June 1980 was traced to 46 mm in December 1980. By taking the age of modal length at 30 mm as 7 months, the modal length at 46 mm in December was assigned 13 months age. It was also observed that there were modes at 42 mm in 6 months from January to June 1980 (Fig. 10). In 1981 there was a mode at 42 mm in January and at 46 mm in February and March (Fig. 10).

Mode C at 26 mm in April 81 progressed to 38 mm by August. By taking the age of the modal length at 26 mm as 5½ months, the modal length at 38 mm in August 1981 was estimated as 9½ months old. There were also modes at 38 mm in three months during September-November 1981.

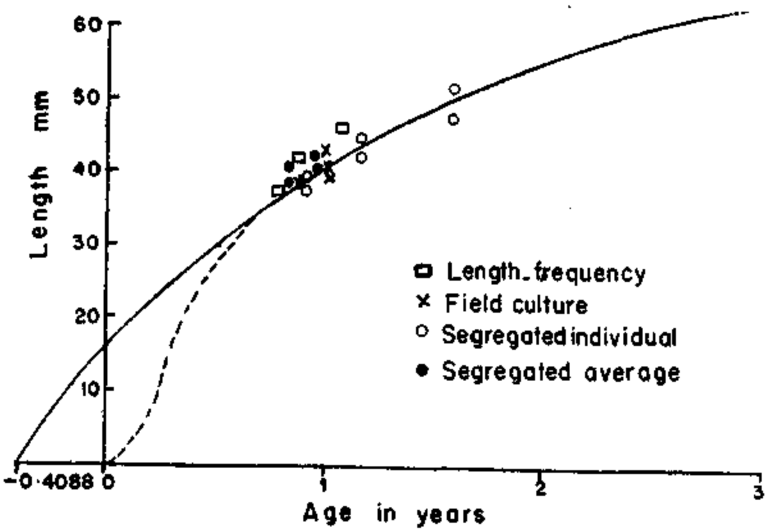

FIG. 8. The von Bertalanffy growth curve in *A. granosa*. Broken line represents the average growth of 5 clams of the length range 4-5 mm. Boxes show the growth by length frequency analysis and hollow circles indicate the individual growth of clams in boxes. Also included are growth data by field culture experiments and average growth of clams which are segregated and grown at different densities in boxes (Narasimham, 1985).

Estimation of the parameters of the von Bertalanffy growth equation : The Manzer and Taylor (1974) plot of L_{t+1} against L_t of the 65 clams (Table 4) showed that the growth data of the first 20 clams do not fall in line with the values of the other 45 clams. Hence the regression line was fitted for the points pertaining to the latter 45 specimens (Fig. 11) The values of L_∞ and K were estimated at 73.4 mm and 0.5816 per year respectively. It was already shown that 43.9 mm long clams are 14 months old (1.17 years). Taking this length as the basis the lengths at successive ages were calculated using the equation of the Manzer and Taylor plot (1947) and the value of t_0 was estimated as —0.4088 year. The von Bertalanffy growth equation for *A. granosa* is written as $L_t = 73.4 \{ 1\text{-}\exp [-0.5816 (t+0.4088)]\}$ where L_t = length in mm at time t. From this equation the calculated lengths collections measured 71.2 mm (estimated age 5.6 years) and this length is close to the $L\infty$ value obtained.

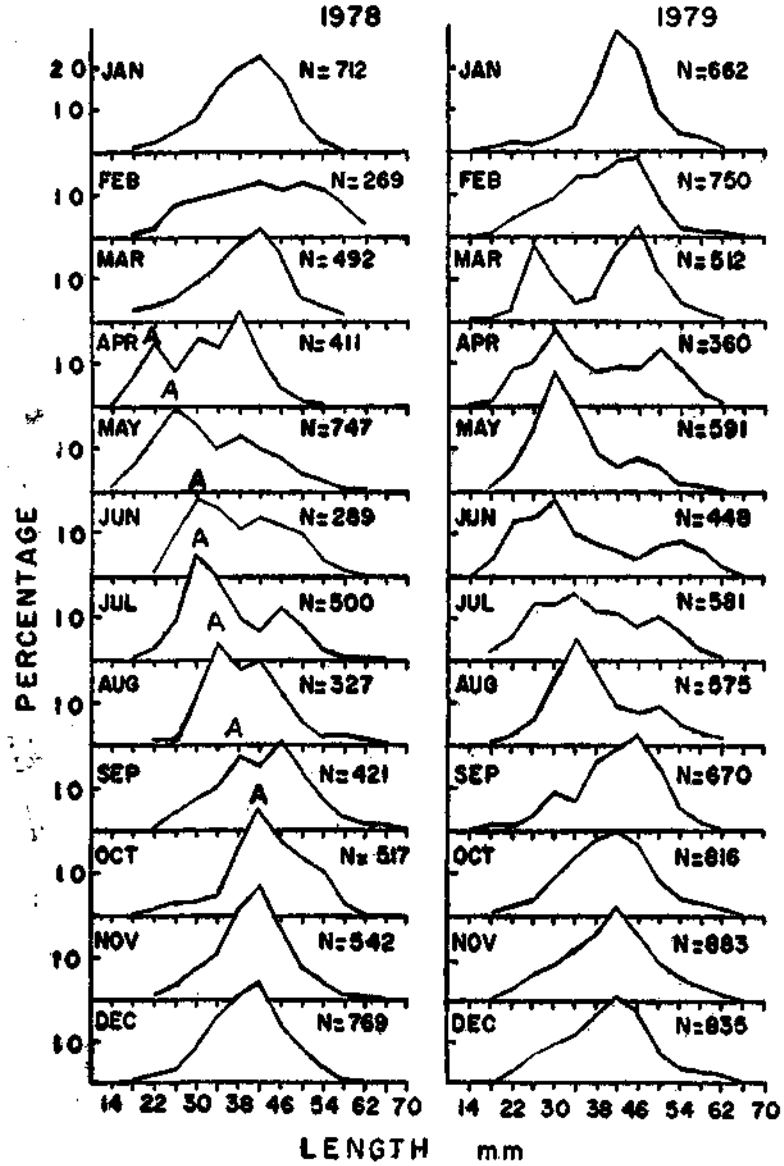

FIG. 9. Monthly length frequency distribution of *A. granosa* during 1978-79.

at ages 1 to 5 are 41.1, 55.3, 63.3, 67.7 and 70.2 mm respectively. The growth curve (Fig. 8) fits well to the observed data from about the 5th month onwards. The largest clam in the

Relative growth during different quarters : The average percentage increase in length of individual clams during the first quarter (29.3.79 to 30.6.79) was the highest at 41.2, followed by 25.2 and 11.4 in 2nd and 3rd quarters respectively. However the 4th quarter registered faster growth of 21.4% compared to the preceeding two quarters. This indicates a period of accelerated growth following a period of slow growth.

Morphometric and Length-Weight Relationships

The various parameters studied and the relationships obtained are given in Table 5. The r values varied from 0.9654 to 0.9956 indicating high degree of correlation between the parameters studied. The b values in the length-weight relationships varied from 2.1277 to 2.8382.

Discussion

In an earlier study Narasimham (1969) stated that in the Kakinada Bay, *A. granosa* spawns throughout the year with peak activity in January and April. From Malaysia, Pathansali (1966) stated that this species spawns throughout the year with a peak during June-October and according to Broom (1983) there is year round spawning. There is agreement on these observations regarding the duration of spawning. However, major spawning months differ between localities. The present study

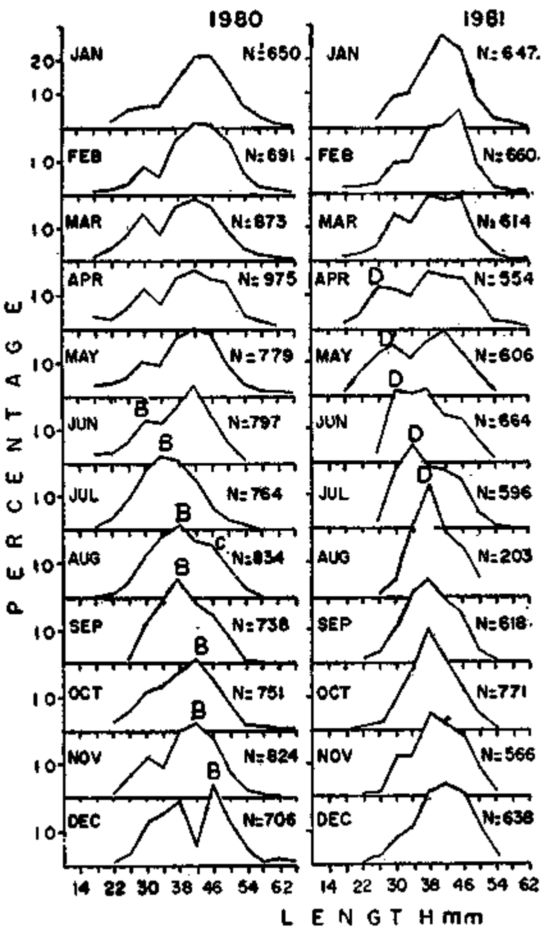

Fig. 10. Monthly length frequency distribution of *A. granosa* during 1980-81.

Table 5. *Estimates of the parameters for morphometric and length-weight (after logarithmic transformation) regression equations in* A. granosa. *Length (X) is taken as the independent variable.*

Dependent variable		Length range mm	Numbers	a	b	r
Height	..	15.5—71.2	135	1.0179	0.7847	0.9956
Width	..	15.5—71.2	135	0.9708	0.7095	0.9899
Hinge	..	15.5—71.2	135	1.0217	0.7415	0.9907
Total weight	..	20.5—71.2	106	—2.8056	2.6212	0.9924
Shell weight	..	20.5—71.2	107	—2.9672	2.5953	0.9935
Wet meat weight	..	20.5—71.2	107	—2.7279	2.1277	0.9855
Dry meat weight	..	18.4—60.9	97	—4.4839	2.8382	0.9654

also shows that major spawning months may differ between years from the same locality.

Narasimham (1969) stated that *A. granosa* in the Kakinada Bay showed mature gonads around 18 mm length and that majority showed ripe gonads from 21 mm onwards. In Malaysia, according to Pathansali (1966) the species attains sexual maturity at 18-20 mm length and Broom (1983) observed that the gonads did not develop until 17.5 mm length and that the first spawning probably occurred at 24-25 mm. The present study on *A. granosa* shows that the length at first maturity in males is 20 mm and in females 24 mm, thus conforming to the above findings. This study also shows that females attain maturity and spawn at a slightly larger length than males.

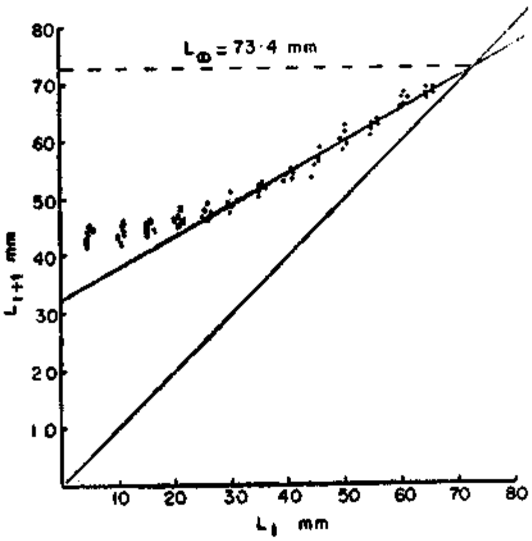

FIG. 11. Manzar and Taylor plot using the growth data of 65 individuals of different lengths in *A. granosa*. Data shown by crosses are not used in fitting the regression equation.

Pathansali (1966) did not find any evidence of deviation of sex ratio in *A. granosa* from 1 : 1. Broom (1983) observed that the sex ratio in this species was not significantly different from 1 : 1 in any of the length groups examined. Of the 300 specimens studied by him there was a single hermaphrodite and he stated that there was no evidence of sex reversal in this species. In the present study also the sex ratio during different months, years and also in different length groups conformed to 1 : 1. Though 4200 specimens were examined in the present study, not even a single instance of hermaphroditism was observed which suggests that sex is stable in *A. granosa*.

Hickman and Illingworth (1980) studied the CI in the mussel *Perna canaliculus* by employing different methods and found significant correlation between the values obtained by various methods. In *A. granosa* in the present study also significant correlation was noticed in the CI values obtained by the two methods employed, suggesting the high degree of interrelationship of the parameters.

In some bivalves the CI in relation to length/volume was found to vary (Baird 1958, Hickman and Illingworth, 1980; Narasimham, 1984). However, in *A. granosa* the CI did not vary in different length groups indicating that the proportion of meat weight in total weight is uniform during growth.

Among the various factors know to affect the condition in bivalves reproductive cycle, infestation by other organisms and environmental parameters are considered important. In *A. granosa* it was observed that the CI was high just before or at the beginning of the spawning and low when the spawning was completed. In the same species from Malaysia, Broom (1983) also found similar relationship between spawning and CI. Similar situation was observed in other bivalves also (Durve 1964, Ansell et al. 1964, Alagarswami 1966 and Narasimham 1980).

In the present study it was observed that on an average 10.8% of *A. granosa* were infested by the pea crab *Pinnotheres alcocki*. From Porto Novo, Patel and Patel (1974) also found that 5-10% of *A. granosa* were infested by pea crabs. Damage to gills mantle and other soft parts is known to occur in some bivalves due to peacrab infestation (Orton, 1921 ; Strauber, 1945 ; Silas and Alagarswami, 1967 ; Narasimham, 1984). However, Krishna Kumari and Rao (1974) did not observe any damage in *Paphia malabarica* infested by *P. vicajii.* In the present study also there was no injury to the soft parts of *A. granosa* infested by the pea crab.

In some bivalves the condition is said to be adversely affected due to infestation by pea crabs (Sandoz and Hopkins, 1947 ; Haven, 1959) while in others it was reported that the CI was not affected by the pea crab infestation (Christensen and McDermott, 1958 ; Krishna Kumari and Rao, 1974). In the present study in *A. granosa* though the CI in the crab infested clams was lower than that obtained in the uninfested ones, statistically significant lower CI was observed only in 41.1% of the clam samples studied.

Theisen (1973) observed that in *Mytilus edulis* the growth curve (in length) is of sigmoid form and that the von Bertalanffy growth equation gave the best fit to the observed length data pertaining to above ⅓rd of the maximum length. He further opined that the sigmoid growth curve is probably common to most lamellibranchs. The growth curves for weight and length of many organisms are sigmoid (Crisp, 1984) and among the bivalves sigmoid growth curves were observed by Stevenson and Dickie (1954), Ansell and Parulekar (1978) and Broom (1982). In the present study also the growth curve in length was found to be of sigmoid form and the von Bertalanffy growth equation describes the growth of *A. granosa* well, when fitted to the length data of clams, measuring above 25 mm length.

Based on the length frequency studies, Narasimham (1969) stated that in the Kakinada Bay *A. granosa* attains 31.5 mm and 49.5 mm on completion of 1 and 2 years respectively. However, in the present study, where a direct method of studying the growth was followed, faster growth rate in the species was observed. In Malaysia, *A. granosa* was reported to attain 27.0 mm 37.0 mm and 43.0 mm on completion of 1-3 years respectively (Fig. 4 of Pathansali, 1964). Also from Malaysia Broom (1982) estimated the von Bertalanffy growth equation parameters as $K = 1.01$ and $L_\infty = 44.4$ mm and the largest specimen in his collections seldom exceeded 45 mm in length. In the Kakinada Bay *A. granosa* grows much faster and also attains much higher maximum length when compared with the results obtained in Malaysia.

Retardation of growth rate in bivalves due to low salinities is known in Indian waters (Rao, 1952 ; Rao *et al.*, 1964 and Mane, 1976). During the period when *A. granosa* was grown in boxes the variations in the monthly average temperature were small within a narrow range (27.8-33.5°C) whereas salinity showed much wider range (13.69-34.40 ppt) ; the lowest salinity value was in November 1979 followed by 15.30 ppt in December 1979 (Narasimham, 1985). The slowest rate of 11.4% of the annual growth was observed in *A. granosa* during the quarter ending December 1979 and this may be probably due to the low salinities in November-December.

Patel and Patel (1974) described the length-breadth and length-height relationships in *A. granosa.* They obtained the equation $W = 0.35\ L^{2.74}$ to describe the length-total weight relationship. Both the elevation and slopes of this equation were found to be beyond the 99% confidence limits of the parameters obtained in this study.

References

ALAGARSWAMI, K. 1966. Studies on some aspects of biology of the wedge clam *Donax faba* Gmelin from Mandapam coast in the Gulf of Mannar. *J. Mar. biol. Ass. India*, **8** (1) : 56-75.

ANSELL, A. D., F. A. LOOSMORE AND K. F. LANDER 1964. Studies on the hard shell clam *Venus mercenaria* in British waters. II. Seasonal changes in condition and biochemical composition. *J. Appl. Ecol.*, **1** (1) : 83-95.

——— AND A. H. PARULEKAR 1978. On the rate of growth of *Nuculana minuta* (Muller) (Bivalvia: Nuculanidae). *J. Mollusc. Stud.*, **44** : 71-82.

BAIRD, R. H. 1958. Measurement of condition in mussels and oysters. *J. Cons. Perm. int. Explor. Mer.*, **23** : 249-257.

BROOM, M. J. 1982. Analysis of the growth of *Anadara granosa* (Bivalvia : Arcidae) in natural, artificially seeded and experimental population. *Mar. Ecol. Prog. Ser.*, **9** : 69-79.

BROOM, M. G. 1983. Gonad development and spawning in *Anadara granosa* (L.) (Bivalvia : Arcidae). *Aquaculture*, **30** : 211-219.

CHRISTENSEN, A. M. AND J. J. MCDEVMOTT 1958. Life history and biology of the oyster crab *Pinnotheres ostreum* Say. *Biol. Bull.*, **114** (2) : 146-179.

CRISP, D. J. 1984. Energy flow measurements. In : N. A. Holme and A. D. McInTyre (Ed.) *Methods for the study of Marine Benthos*. IBP Handbook No 3, Second edition, Blackwell and Scientific publications, Oxford, pp. 284-372.

DURVE, V. S. 1964. On the percentage edibility and the index of condition in the oyster *Crassostrea gryphoides* (Schlotheim). *J. mar. biol. Ass. India.*, **6** (1) : 128-135.

HAVEN, D. 1959. Effects of peacrabs *Pinnotherus ostreum* on oysters *Crassostrea virginica*. *Proc. Natl. Shellfish. Ass.*, **49** : 77-86.

HICKMAN, R. W. AND J. ILLINGWORTH 1980. Condition cycle of green-lipped mussel *Perna canaliculus*, in New Zealand. *Mar. Biol.*, **60** : 27-38.

KRISHNAKUMARAI, L. AND K. V. RAO 1974. Life history of the peacrab *Pinnotheres vicajii* Chapgar infesting the clam *Paphia malabarica*. *Indian J. Mar. Sci*, **3** (2) : 165-172.

MANE, U. H. 1976. Growth and breeding habits of the clam *Katelysia opima* in the Kalbadevi Estuary at Ratnagiri. *Indian J. Fish.*, 1974, **21** (2) : 386-398.

MANZER, J. I. AND F. H. C. TAYLOR 1974. The rate of growth in lemon sole in the strait of Georgia. *Progr. Rep. Pacific est. stus*, **72** : 24-27.

NARASIMHAM, K. A. 1969. Studies on some aspects of biology and fishery of the Cockle *Anadara granosa* (Linnaeus) from the Kakinada Bay. *Proc. Symp. Mollusca*. Mar. Biol. Ass. India, **2** : 407-417.

——— 1973. On the molluscan fisheries of the Kakinada Bay. *Indian J. Fish.*, **20** (1) : 209-214.

——— 1980. Fishery and biology of the green mussel *Perna viridis* (Linnaeus). In : *Coastal Aquaculture : Mussel farming progress and prospects* ; *Bull. Cent. Mar. Fish. Res. Inst.*, **29** : 10-17.

——— 1983. Experimental culture of the blood clam *Anadara granosa* (Linnaeus) in Kakinada Bay. *Proc. Symp. Coastal Aquaculture*, Mar. Biol. Ass. India, **2** : 551-556.

——— 1984. Biology of Windowpane oyster *Placenta placenta* (Linnaeus) in Kakinada Bay. *Indian J. Fish.*, **31** : 272-284.

——— 1985. Studies on some aspects of the biology and fishery of the Blood clams *Anadara* (*Tegillarca*) *granosa* Linnaeus (1758) and *A.* (*T.*) *rhombea* Born (1780) from the Kakinada Bay. *Ph.D. Thesis. Andhra University, Waltair* : 262 pp.

ORTON, J. H. 1921. The mode of feeding and sex phenomena in the pea-crab (*Pinnotheres pisum*). *Nature*, **106** : 533-534.

PATEL, B. AND S. PATEL 1974. Blood clams - Material for physiological and biochemical studies. *J. mar. biol. Ass. India*, (1972), **14** (2) : 555-563.

PATHANSALI, D. 1966. Notes on the biology of the Cockle *Anadara granosa* (L.). *Proc. Indo-Pacific Fish. Counc.*, **8** (2) : 84-98.

RAO, K. V. 1952. Studies on the growth of *Katelysia opima* (Gmelin). *Ibid.*, (2) : 94-102.

———, K. A. NARASIMHAM AND K. ALAGARSWAMI 1964. A preliminary account of the biology and fishery of the razor-shell *Solen kempi* Perston from Ratnagiri in Maharashtra State. *Indian J. Fish.*, (1962) **9** (2) : 542-579.

ROPES, J. W. 1968. Reproductive cycle of the surf clam *Spisula solidissima* in offshore New Jersey. *Biol. Bull.*, **135** (2) : 349-365.

SANDOZ, M. AND S. H. HOPKINS 1947. Early life history of the oyster crab *Pinnotheres ostreum* (Say). *Ibid.*, **93** : 220-258.

SILAS, E. G. AND K. ALAGARSWAMI 1967. On an instance of parasitisation by the pea-crab (*Pinnotheres* sp.) on the backwater clam *Meretrix casta* (Chemitz from India, with a review of the work on the systematics, ecology, biology and ethology of peacrabs of the genus *Pinnotheres* Latreille. *Proc. Symp. Crustacea.*, Mar. Biol. Ass. India, **3** : 1169-1227.

SNEDECOR, G. W. AND W. G. COCHRAN 1967. *Statistical methods*. Oxford and IBH publishing co., Calcutta. 593 pp. (Revised edition).

STEVENSON, J. A. AND L. M. DICKIE 1954. Annual growth rings and rate of growth of the Scallop *Plagopecten magellanicus* (Gmelin) in the Digby area of the Bay of Fundy. *J. Fish. Res. Bd. Can.*, **11** : 660-671.

STRAUBER, L. A. 1945. *Pinnotheres ostreum*, parasitic on the American oyster *Ostrea* (*Gryphea*) *virginica*. *Biol. Bull.*, **88** : 269-271.

THEISEN, B. F. 1973. The growth of *Mytilus edulis* L. (Bivalvia) from Disco and Thule district, Greenland. *Ophelia*, **12** : 59-77.

WONG, T. M. AND T. G. LIM 1985. Cockle (*Anadara granosa*) seed produced in the laboratory. *ICLARM Newsletter, Malaysia*, 8 (4) : 13.