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26. BIOLOGY OF THE BLOOD CLAM, *ANADARA RHOMBEA* (BORN) IN KAKINADA BAY

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ABSTRACT

A. rhombaa **occurs in small qusntities in the Kakinada Bay and is incidentally collected while fishing foi the moie abundant *A. granosa-* Males attain maturity at 22 mm and females at 24 mm length. It spawns during December-April (rarely in May) and major spawning Is indicated in Januaiy-March. A single or two reproductive cycles occur during the spawning period. Increase in the ambient water temperature and salinity seem to induce spawning The proportion of males and females during dif'etent months, years and also in different length gioups generally conforms to 1:1 ratio. The average monthly condition index (CI) expressed as percentage of wet flesh weight in total weight, vsries from 9 6 to 15 7. The CI does not vary in relation to length. It is high before or at the beginning of spawning and low when majority of the clams hive released bulk of the gametes. In the post-spawning period the CI Is again high, probably due to the accumulation of body reserves. The estimatad values of the parameters of the yon Beitalanffy growth equation ate Lco'=90.2mm, K = 04573 per year and t" = "0 6315 yr. *A. rhombea axxa'ms* 47.4,63.1 and 73.1mm on completion of 1, 2 and 3 years respeotivaly. Various morpho netric and length-weight relationships are studied-**

INTRODUCTION

The blood clam, >^ r/}0/w6ea occurs in stray numbers in the Kakinada Bay and is caught incidentally while fishing for 4. flrra/josa. Except for a study on maturity, spawning and sex ratio from Porto Novo backwaters by Natarajan and John (1983,) there appears to be no other published information on the biology of *A. rhombea.*

MATERIAL AND METHODS

Fortnightly samples of about 25 clams were collected during 1978-81 from the fishermen catches and supplemented by grab collections. Spawning and sex ratio were studied by examining the gonad smear in 1944 clams and gonad sections of 360 clams of the length range 33-89 mm. Standard histological techniques were followed to cut 7-10 mm 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 84 clams measuring 13.5-28.8 mm and collected in March 1979 when there was a peak spawning. The test of variance of homogeneity (Snedecor and Cochran 1967) was applied to test the significance of differences in the proportion of males in the monthly samples. It was next ascertained by the Chi-square test whether the observed monthly sex ratio differed from the theoretical 1:1 ratio. This test was not applied if the number of specimens was below nine. The condition index was calculated as percentage of wet flesh weight in total weight. The condition in relation to length was studied in 75 clams measuring 41-80 mm and collected

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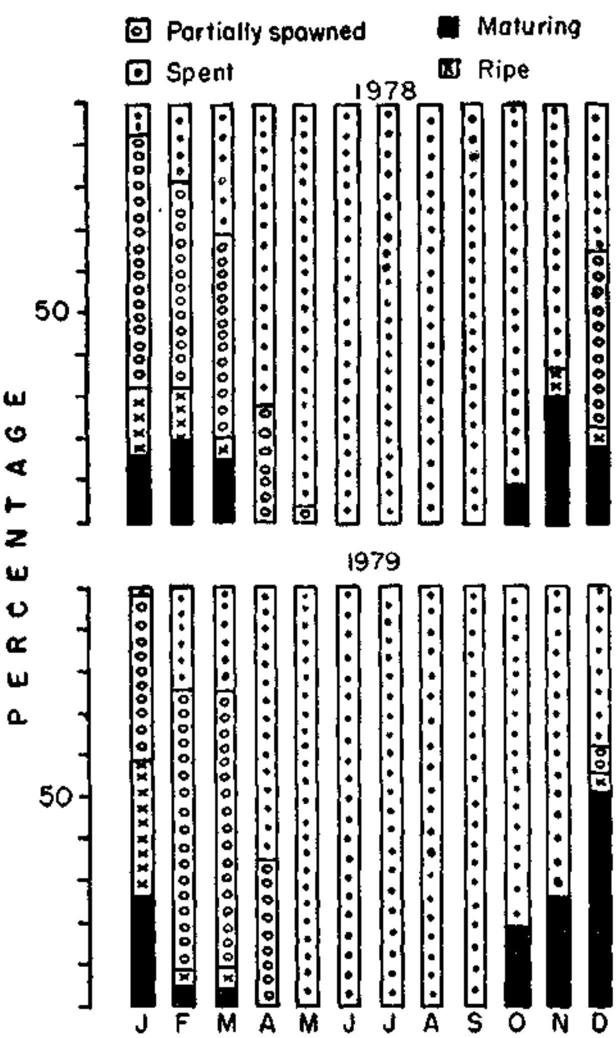
during October 1979 when there was no spawn- '"9-, Age and growth was studied by growing 56 clams of length range 9.0-82,5 mm for one *V^^'* '" dealwood boxes measuring 50 cm x 50 cm x 15 cm and divided into 9 compartments, ^^^^ compartment was filled with sediment obtained from the clam bed, a measured clam ^as introduced in it and the box was placed in the clam bed. Further details were given by Narasimham (1983). The values of Leo and to in the von Bertallanffy growth equation were estimated by the Manzer and Taylor (1947) P'ot The relationship between length and other body measurements was studied by fitting the regression equation of the type Y= a-I-bX; where required logarithmic transformation was applied. The dry meat weight of the clam was recorded after keeping the flesh in hot air oven for 48 h at 80°c±1. All linear measurements were taken to the nearest 0.1 mm with a vernier calipers and weight data recorded to the nearest mg in electric balance.

SPAWNING

January-September 1978 During January-March maturing (Pl. Ia, Pl. 2 a) and ripe (Pl. 1 b and c, Pl. 2 b and c) clams formed 14.8-19.4% and 5.6-16.0% respectively (Fig 1). The number of partially spawned clams (Pl. 1d, Pl. 2d) was high at 60% in January followed by February-March (about 48%) indicating major spawning h these months. In April the partially spawned



Flo 1. Monthly percentages of different «,aturity .t.ge. in A. rftomdea during 1978-79.

clams formed 27.3% and they released bulk of the gametes; in May their number was reduced to 4.2% indicating the completion of the reproductive cycle. The spent clams (Pl. 1e, Pl. 2 e) increased progressively from 8% in January to 95.8% in May and all were spent in June-September.

October 1978-September 1919 Maturation was mitiated in October and during November-January maturing clams formed 17.5 to 33 9% (Fig.l). There was spawning during December-April when 34.5-67.3% of the clams showed partially spawned gonads. There was major spawning in January-March. The gametes were mostly released by March-April. The spent clams increased from 1.9% in January to 65.5% towards the close of the reproductive cycle in April and in the following five months all were in spent stage.

October 1979-September 1980 Maturing clams increased from 18% in October to 81.6% in January (Fig 1 and 2) and in the following three months they formed 10-20.4%. The distribution of partially spawned clams shows that spawning was initiated in December and it continued till April with peak activity during February- March. Spent clams were absent in January and their number gradually increased to 58.3% by April; in May-September all were in spent state.

October 1980-October 1981 Maturing clams first appeared in October 1980 andtheirnumber increased to 70% by December and declined to 6.4% in January (Fig 2). Spawning commenced in December, touched peak in January when 68.1% of the clams were in partially spawned stage. The spent clams showed a reduction from 68% in October to 4% in December and a slight increase to 19.1% in January.

The sharp increase of maturing clams from 4% in January to 59.2%, in February (Fig 2) indicates the commencement of another reproductive cycle within the spawning period. The maturing clams declined to 16.7% in March and were absent in April. There was spawning In February-April and the follicles were almost **«'"P*y «* the close of April. All the clams were** in spent stage during May-October 1981.

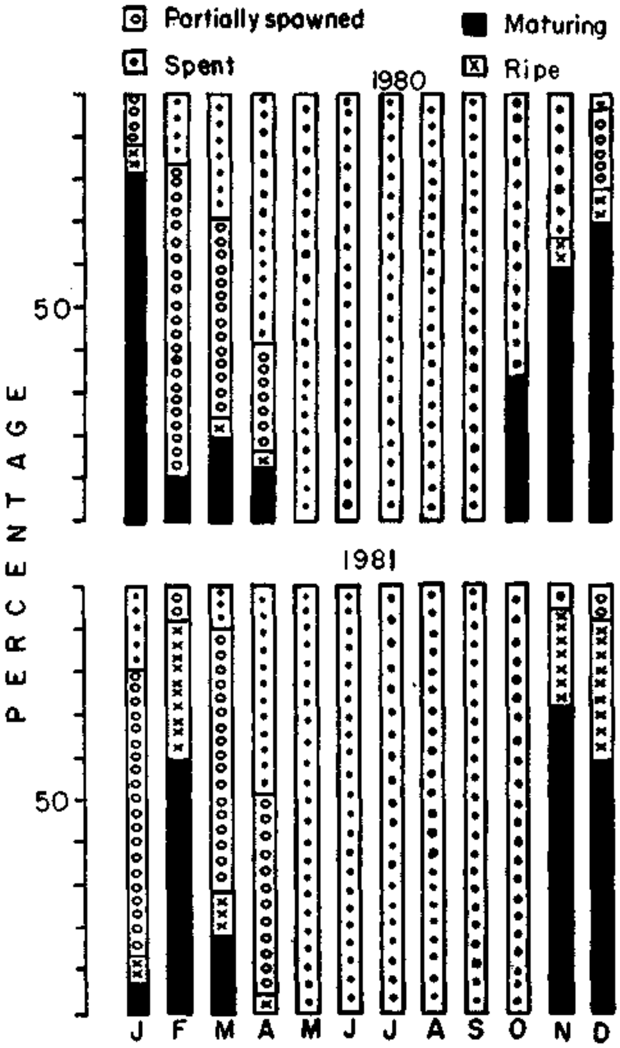


Fig 2. Monthly percentages of different maturity stages A. rhombea during 1980-81.

November - December 1981 **Majority of the clams had maturing gonads in these two months (Fig 2) and spawning commenced in December.**

LENGTH AT FIRST MATURITY

The gonad was not developed in 14 and 16 mm length groups (Table 1). In the next group, 7 clams were in indeterminate stage and three were maturing males. In the 22 mm group majority (62.5%) were mature males and in 28 mm group all the males were mature. Partially spawned and spent males were first observed in 24 and 28 mm length groups respectively. In males the length at first maturity was taken as 22 mm.

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

Length mm	Sex	N	Maturing	Ripe	Partially spawned	Spent/ resting
14	Indt	6	—	—	—	—
16	Indt	8	—	—	—	—
18	Indt	7	—	—	—	—
	Male	3	100.0	—	—	—
	Female	—	—	—	—	—
20	Indt	4	—	—	—	—
	Male	8	100.0	—	—	—
	Female	—	—	—	—	—
22	Male	8	37.5	62.5	—	—
	Female	2	100.0	—	—	—
24	Male	6	16.7	66.7	16.7	—
	Female	2	50.0	50.0	—	—
26	Male	9	11.1	33.3	55.6	—
	Female	5	20.0	40.0	40 0	—
28	Male	10	—	30.0	50.0	20.0
	Female	6	16.7	33.3	33.5	16.7

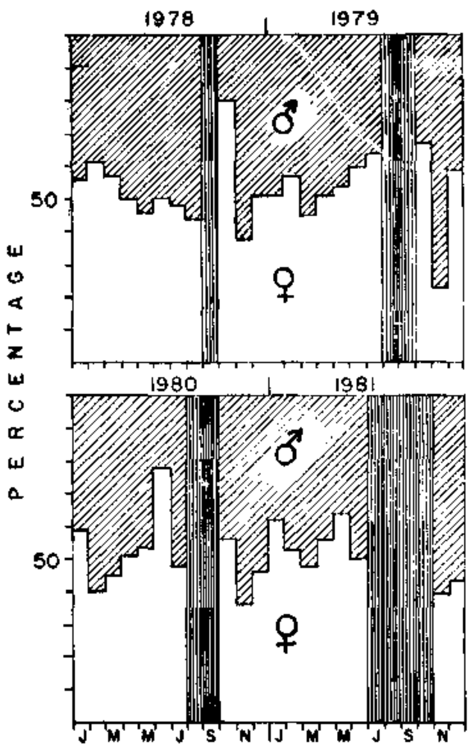
Indt = Indeterminates.

Females were first observed in the 22 mm length group (Table 1) and in the next length group 50% of them were mature. Partially spawned and spent stages occurred for the first time in 26 and 28 mm length groups respectively. Thus females attained first maturity at 24 mm length, at a slightly larger size than males.

SEX RATIO

During April-December of different years the sex of some or all the spent adult clams examined could not be determined as they passed into indeterminate (resting) phase. In September 1978, August-September of 1979 and 1980 and July-October 1981 all the clams were indeterminates (Fig 3).

Females outnumbered males in most of the months f'Fig 3). The test of heterogeneity for variance showed that at 5% probability the Chi-square values during different years are



Flo 3. Monthly peroentagw of malM and ftmiLs during different years in >t. r/iom/)sa. (Long vertical line* show the months when all the clamS examined could not be sexed).

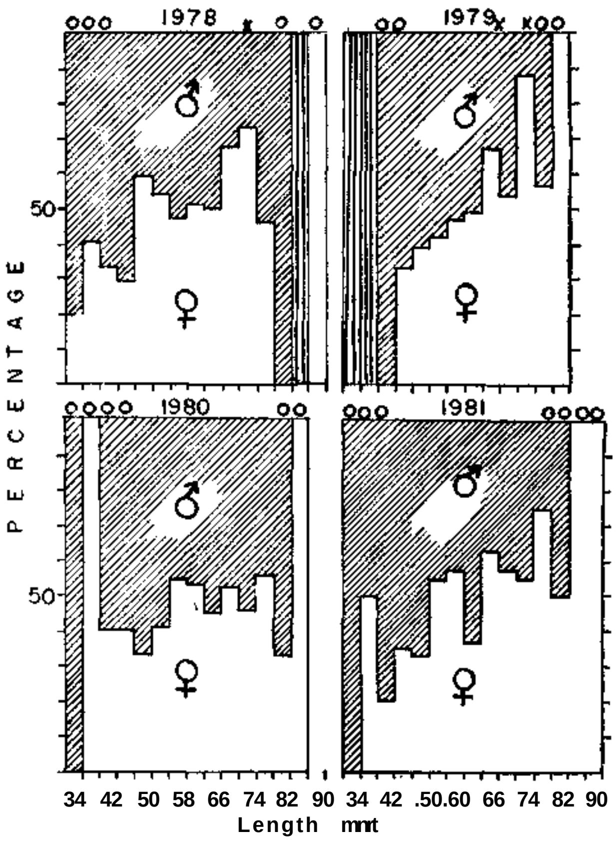


Fig A. Sex ratio in different length gioups during 1978-81 in A. fhombea [Vertical lines indicate absence of date, circles mdicate that Chi-square ,est not conducted due to small sample size. Crosss indicate Chi-squire value significant at ^/^ probability.]

. .,. ,» , , „v -r. r^, • ^ . not Significant (Table 2). The Chl-square test on the monthly sex ratio (October 1978 test not conducted) revealed that only in June 1980 the ratio differed significantly at 5% from the theoretical 1 : 1 ratio during the four year study

^ •"

TABLE 2. *Test of homogeneity {XI) for proportion of males in monthly samples of* A. rhombea *during 1978-81*

^»°'"	d^	X'	Significanc* at 5%
1978	10	6.04	Not significant
1979	9	8 68	"
1980	9	12.75	„
1981	7	7.46	,,

The data on sex ratiD in relation to length (Fig 4) showed that in 1978, malas were dominant in 34-46, 58 and 78 mm length groups: they formed 100% in the 82 mm group. in the remaining length groups females out-numbered males (in 62 mm group the ratio T"' """^ !." |^' ^° ""^ ^'""^ °"'^ °"^ ^^"^^'^ *oocuueA).* The Chi - square test showed that the male: female ratio was not significantly different from the expected 1 : 1 ratio at 5% except in the 74 mm group when females dominated The data for 1979-81 indicated the same trend wz dominance of males in smaller length groups, female dominance in the rest of the length groups with few exceptions and all the clams in the 83 and 9D mm groups were females. The XMest showed that during thasa three years the male : female ratio was not significatly different from the expected 1 : 1 ratio at 5% in ail the length groups for which the test was conducted excepting the 66 and 74 mm groups in 1979.

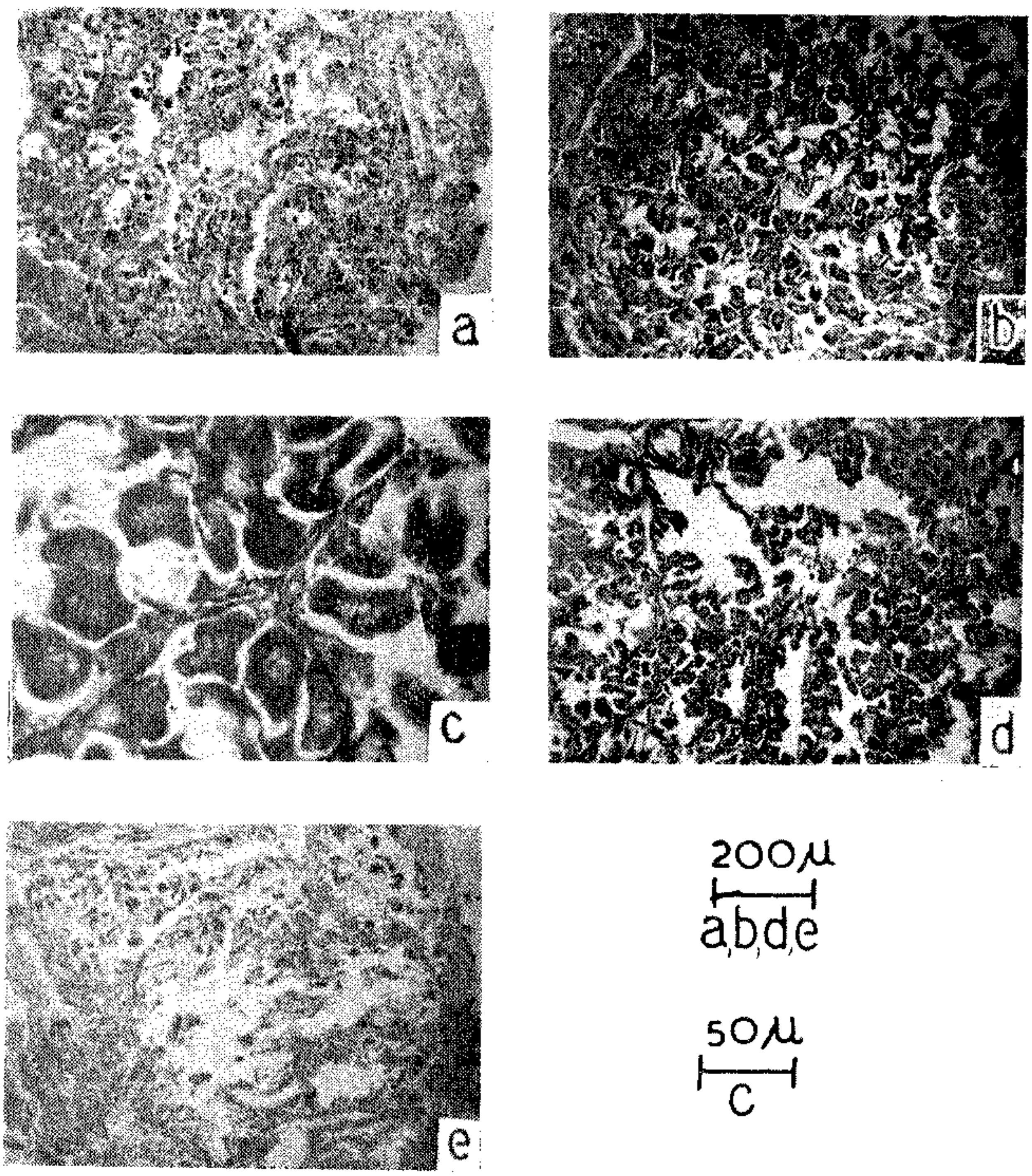


PLATE 1 (Female) a. Maturing stage showing developing oocytes of various sizes.
b. Ripe stage with densely packed ova and some ova appear free in the enlarged follicles.
c. Ripe stage at higher magnification. The ripe ova are polygonal in shape, diameter ranges from 49 to 61 mm and the nuclei measure 22-33 mm.
d. Partially spawned stage with some ripe ova in some follicles while other follicles are empty.
e. Spent stage with residual ova undergoing cytolysis.

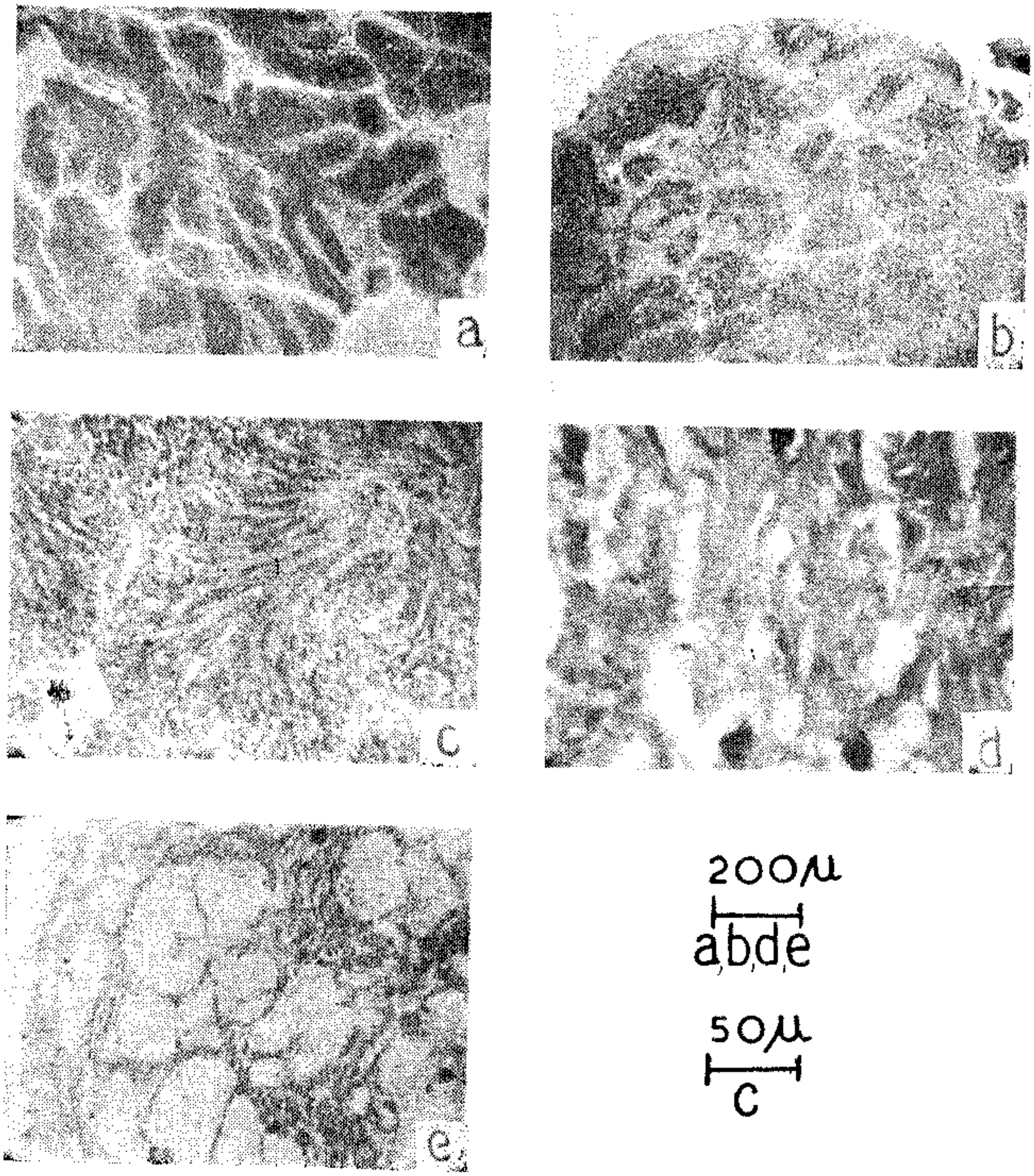


PLATE II (Male) a. Maturing stage showing many developing follicles.
b. Ripe stage showing many follicles densely packed with spermatozoa.
c. Ripe follicle at higher magnification. Mature sperms arranged in radial streaks with tails towards the centre of follicles.
d. Partially spawned stage with moderate quantity of spermatozoa in some follicles while other follicles aremostly empty.
e. Spent stage with many empty follicles and residual spermatozoa.

Though deviations in the sex ratio were observed in one month and on three occasions in different length groups, since they are few and may be due to sampling variation, it is concluded that the male : female ratio conforms to 1 : 1.

CONDITION INDEX

Condition index in relation to length. The individual values of the condition index in the sample varied from 9.3 to 17.4 and in each length group the range of variation and the mean were more or less the same over the length range studied (Fig 5). Analysis of variance showed that the CI between the length groups is not significantly different at 5% (Table 3). In other words the CI does not vary with growth.

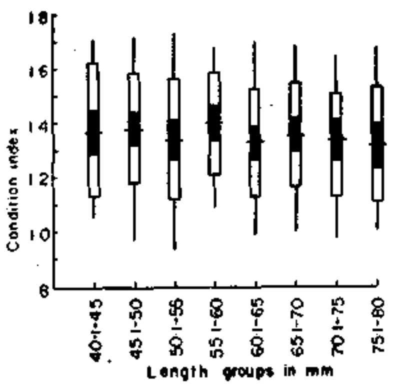


Fig 5. Condition index in different length groups in *A. rhombea*. The vertical line (not depicted in the area showing S. E and S. D) shows the range, the small horizontal line the mean, the shaded and open boxes together one standard deviation and the shaded box alone one standard error on either side of the mean.

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

Source of variation	d f	S. S.	M. S	F
Between size groups	7	4.68	0.6686	
				0.152
within groups	67	293.85	4.3858	
Total	74	298.53		

F (d f 7, 67) 5% = 2.15

Seasonal changes in the condition index. The average CI during different months varied from 9.6 in June 1980 to 15.7 in November 1978 (Fig 6) with an average of 13 2.

In 1978 the CI steadily declined from January, touching the lowest value in April (Fig 6). Thereafter, notwithstanding the slight fall in August, it remained fairly high. During 1979 the CI was high in January, low in March-

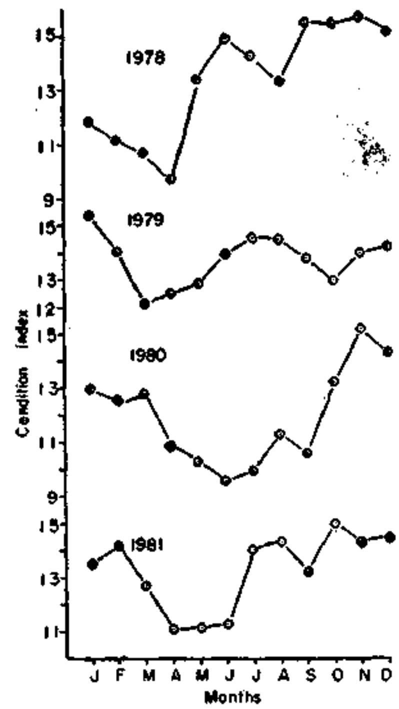


Fig 6. Monthly average condition index based on wet flesh weight in *A. rhombea* during 1978-81

April, steadily increased to touch high values in July-September and November - December, excepting for a slight fall in October. The CI was high during January-March 1980, low during April-September, increased in October and remained high during November-December. In 1981, the CI was high during January-February, low in April-June and it remained high during July-December except for a slight fall in September.

The trends in the CI values during different years are comparable, barring a few exceptions. In January the CI was high, low in April-May and was fairly high in the second half of the year.

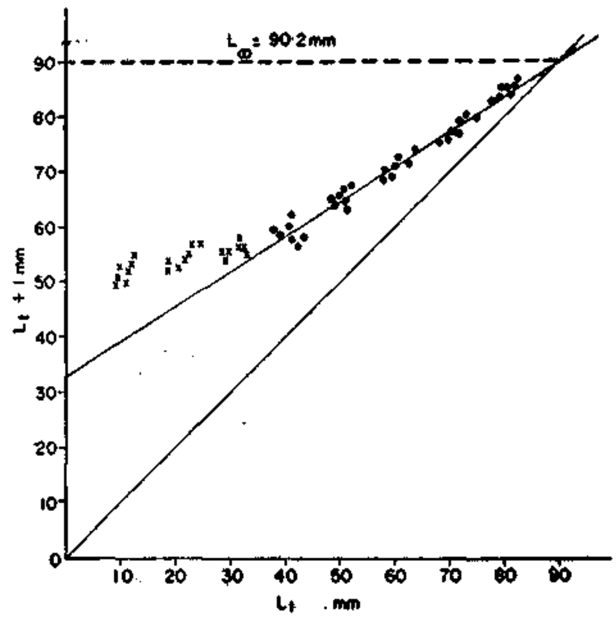


Fig 7. Manzer and Taylor plot using growth data of 56 individuals of different lengths of *A. rhombea* Data by crosses not used in fitting the regression equation.

AGE AND GROWTH

Growth of clams in boxes The average growth rate of the clams during a year varied from 0.36 to 3.44 mm/month depending upon the initial size (Table 4). Clams of 10.8 mm average length introduced in the box on 29.3.1979 have grown to 33.2 mm in 3 months, 43.2 mm in 6 months, 46.7 mm in 9 months and 52.1 mm in one year (Table 4, S. No 1). Similar data are available for the remaining clams but their age when first introduced in the boxes is not known. While there is no information available either on the duration of the larval development or the growth of spat of *A. rhombea* it is known that the larvae of allied species, *A. granosa* settled after 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 9 weeks for the spat to attain 10.8 mm length it follows that from fertilisation *A. rhombea* grows to 10.8 mm length in 3 months. The observed average lengths in the succeeding months are shown below and also as a broken line in Fig 8.

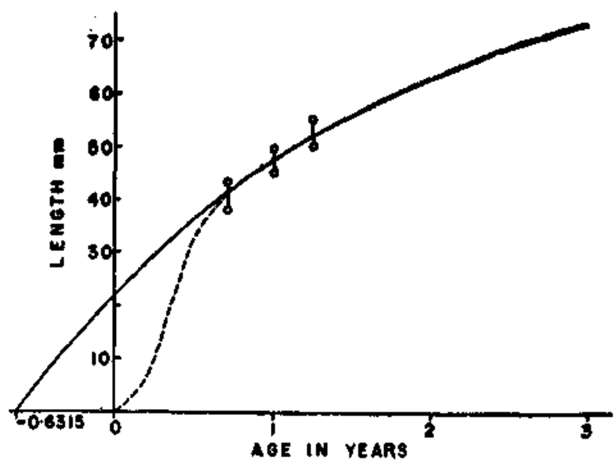


Fig 8. The von Bertalanffy growth curve in *A. rhombea*. Broken line represents the average growth of a class of the length range 9-12.3 mm and circles connected by vertical bar the range in the growth of individual clams studied in boxes.

TABLE 4. *Quartely average growth in length (mm) in* A. rhombea *grown in boxes*

S No.	Length range	No.	29.3 1979	30.6 1979	28.9 1979	30.12 1979	29.3 1980
1.	9.0-12.3	7	10.8	33.2	43.2	46.7	52.1
2.	18.7-24.6	,,	21.4	37.8	46.7	50.0	54.6
3.	28.4-32.8	,,	30.7	42.1	49.3	51.9	56.2
4.	38.1-43.4	,,	40.9	49.5	54.3	56.1	59.1
5.	48.7-52.2	,,	50.4	56.8	60.9	62.6	65.3
6.	58.0-64.1	,,	60.7	66.0	68.4	69.5	71.2
7.	68.2-75.0	,,	71.2	74.6	76.0	76.6	77.7
8.	78.3-82.5	,,	80.4	82.4	83.5	84.0	84.7

._Q j ^QPtf^s	Z	4	5	Q	J	g	g
Averaoe length mm	10.8	18.5	25.6	33.2	36.9	39.1	43.2

In one year the above clams attained 46.7 mm and m 15 months 52.1 mm length (Table 4, °' "

Estimation of tf^eparameters of tf^esionBertalanffy growtf, equation. The Manzer and Taylor plot of L,+i against Lt of the 56 clams (Fig 7) showed that the growth data of the first 21 clams (Table 4, S. No. 1-3) do not fall in line with the values of the other 35 clams. Hence the regression line was fitted for the points pertaining to these 35 specimens (Fig 7). The values of Loo and K were estimated as 90.2 mm and 0.4573 per year respectively. By taking the length of 15 months old clams as 52.1 mm the lengths at successive ages were estimated from the Manzer and Taylor plot. Using these data the value of to was estimated as -0.6315 yr. The von Bertalanffy growth equation in/l. *rfiombaa* IS written as

$$L. = 90.2 [1-\exp [0.4573 (t+0.6315)]$$

where L is length in mm at time t. From this equation the estimated lengths at ages 1-5 are 47.4, 63.1,73.1, 79.3 and 83.3 mm respectively. The growth curve (Fig 8) fits well to the observed data from about the 7th month onwards. The largest clam in the collections measured 89.7mm (estimated age 10 years) and this length is close to the L, value obtained,

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 48.0, followed by 25.6 and 10.6 in 2nd and 3rd quarters respecti- ^"'y- "°^'^"^' '^^ ^"^ ^"^^*"^ ^'9'^'"^"^ ^^'^' 9'°^^^ "^ ^^2% ^""^P^'^^ to the preceeding ^"^^*'"- "^^'^ '"'^'•"*'' ^'^"'^ °^ accelerated growth following a period of slow growth.

MORPHOMETRIC AND LENGTH-WEIGHT RELATIONSHIPS

The various parameters studied and the relationships .obtained are given Table 5. The r values varied from 0.9358 to 0.9976 indicating high degree of correlation between the parameters studied. The b values in the length-weight relationships varied from 2.5053 to 2.9367.

DISCUSSION

Natarajan and John (1983) stated that ^- *r/iombea* spawns during February-September in the backwaters of Porto Novo, in the Kakinada Bay the spawning season in this species is restricted to five months during December-April (rarely in May) with one reproductive cycle (rarely two). It is well known.

TABLE 5. *Estimates o/tfia paramatars for morphomstric and /angth-waigfit (aftar logarithm! transformation) regression equations in* A. rhombea. *Length (X) is taken as the Independent variable-*

S. No.	Dependent variable	Size range mm	Numbers	a	b	r
1.	Height	9.0-89.7	136	3.6180	0.7030	0.9958
2.	Width	9.0-89.7	136	2.9964	0.6962	0.9953
3.	Hinge	9.0-89.7	136	0.8760	0.6274	0.9938
4.	Total weight	9.0-89.7	148	-3.2465	2,9367	0.9976
5.	Shell weight	25.1-89.7	100	-3.3303	2.8973	0.9513
6.	W«t meat weight	25.1-89.7	100	-3.3860	2.5053	0.9892
7.	Dry meat weight	41.6-84.1	125	-4.5384	2.8848	0.9358

that the duration of the spawning period varies in a species occurring in different parts of its geographtc range (Ropes and Stickney 1955 and Seed 1976). Sastry (1979) reviewed the various exogenous and endogenous factors which influence the reproductive cycle in bivalves. Among them temperature and salinity received greater attention, In/4. rAo/nAea spawning took place in a few individuals in December but majority of them spawned during January April. During these four months temperature and salinity in the clam bed showed increasing trend (Narasimham 1985). Similar observations were made by Nagabhushanam and Talikhedkar (1977) in *Donax* cy/jeafus and Nagaphushanam and Mane (1975) in *Katelysia opima* from the Ratnagiri area.

In some bivalves gametogenesis occurs immediately after the completion of spawning (Loosanoff 1953 and Nagabhushanam and Man© 1975) while in others gametogenesis does not occur immediately after the spawning and the sexuality of fhe bivalve is lost (Rao 1967 and Boyden 1971). The present study reveals that /I. r/70/77i6e» belongs to the latter category. Natarajan and John (1983) also observed that at Porto Novo this species passes on to an indeterminate stage after the completion of spawning.

According to Natarajan and John (1983), *A. rhombea* attains first sexual maturity when 21-25 mm long and males mature earlier than females though they did not give the lengths at first maturity for the sexes separately. The present study confirms the above obssrvations.

At Porto Novo, the overall male:female ratio in *A. rhombea* \NSiS 1.27:1 and in male dominated months the sex ratio was significantly different from 1:1 (Natarajan and John 1983). These authors also found that males were dominant in the 20-50 mm length range and females in 55-60 mm length range. However, in the Kakinada Bay tha male: female ratio conforms to 1:1 in all the months and and length groups, barring a few exceptions.

In some bivalves the condition index iu relation to length/volume was found to vary (Baird 1958, Hickman and Illingworth 1980 and Narasimham 1934). In *A. rhombea* the condition index did not vary in different length groups indicating that the proportion of meat weight in total weight is uniform during growth. The condition was high, just before or at the beginning of the spawning and it was low immediately on completion of the spawning. Similar observation was made in other bivalves also ^Durve 1964, Ansell et. al. 1964 and Alagarswami 1966;. Sastry (1970) observed increase in the body weight of scallop *A»quipecten irradians* during the post-spawning period and attributed this increase to accumulation of nutrients in the body. It was observed that during the post-spawning period, *A. rhombea* passes into indeterminate phase with no gonad development; during this period high condition was observed and this may be due to the accumulation of body reserves.

Following tha work of Manzer and Toylor {'1947;, who plotted the individual lengths of recaptured lemon sole against their lengths when tagged one year previously, some authors ('Hancock 1965; Theisen 1973) have called the plot of Lt-Hi against against Lt of *individuals* of different ages as Manzer and Taylor plot. I differs from the more usual Ford-Walford plot (Ford 1933;Walford 1946) which employs the *mean* lengths at each age. Theisen (1973) observed that in *M/ti/us 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 1/3 rd of the maximum length. He wrote "Probably the sigmoid growth curve is common to most lamellibranchs, and hence the von Bertalanffy growth equation should not be used to present the growth of lamellibranchs under about one third of the estimated maximum length." (p. 72). The growth curves for weight and length of many organisms are sigmoid (Crisr 1984) and among the bivalves sigmoid growth curves ware observed by Stevensan and Dickie (1S54) Ansell and Parulekar (1978) and

Broom (1982). In the present study also the growth curve in length was found to be of sigmoid form (Fig 8) and the von Bertalanffy growth equation describes the growth *A. rhombea* well when fitted to the length data of the clam, measurino above 32.8 mm length onwards-

Retardation of the growth rate, in bivalves due to low salinities is know in Indian waters (Rao 1952, Rao ef *si* 1964 and Mane 1976). During the period when *A rhombea* was grown in boxes the variations in the monthly average temperature were small (27.8-33.5°c) whereas salinity showed much wider range (13.69-34.40 ppt); the lowest salinity value was obtained in November 1979 followed by 15.30 ppt in December '79 Narasimham 1985). The slowes. growth of 10.6% of the annual growth in *At rhombea* was observed during the quarter ending December 1979 and this may be due to the low salinities in November-December.

Patel and Patel (1974) described the length-breadth (referred to as width in the present, study), and length-height relationships, in *A rhombea.* These authors have neither mentioned the scale in which ttie measurements were taken nor the length range of the material examined. They obtained the equation W = 0.35L2.74to describe the length-total weight relationship. Both the elevation and slope of this equation were found to be beyond the 99% confidence limits of the parameters obtained in this study.

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