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AGE AND GROWTH OF THE POTAMIDID SNAIL *CERITHIDEA* (*CERITHIDEOPSILLA*) *CINGULATA* (GMELIN) IN VELLAR ESTUARY, SOUTHEAST COAST OF INDIA

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ABSTRACT

Growth of *Cerithidea* (*Cerithideopsilla*) *cingulata* (Gmelin) in Vellar Estuary, estimated based on the length frequency method was 13, 22, 28 and 32 mm in the first, second, third and fourth years respectively. The actual growth was 13 mm (at the rate of 1.08 mm per month), 9 mm (0.75 mm/month), 6 mm (0.5 mm/month) and 4 mm (0.33 mm/month) during the four year period. Slowing down of growth rate was noticed from 19 mm onwards, probably due to attainment of maturity and subsequent breeding activity.

Growth estimated by probability plot method was 9.5 mm to 9.75 mm in the first year, 18.5 to 19.0 mm in the second year, 26.5 to 26.75 mm in the third year and 30.5 to 32.25 mm in the fourth year. Growth observed by marking experiments was 6 mm in 5 months.

Von Bertalanffy's growth equation for estimating the L_t at the age of t is :

$$L_t = 39.99 \left[1 - e^{-0.4054 (t - 0.0971)}\right]$$

Morphometric studies indicated that growth of various body parts in relation to length was linear and isometric. Length-weight relationship of both total and flesh-weight varied between juveniles and adults and therefore two equations have been derived separately :

Total weight	Juveniles	:	-0.0106 + 1.9646 log l
	Adults	:	-0.6646 + 2.6575 log l
Flesh weight	Juveniles	:	-2.3215 + 3.2525 log l
	Adults	;	-1.6383 + 2.7151 log l

Population was composed of 0, 1, 2 and 3 year classes mainly, of which 0-year class was dominant. There was no apparent limiting influence of environmental factors such as food, season, salinity and overcrowding on the growth of *C* (*C.*) *cingulata* in the Vellar Estuary, during the period of study.

INTRODUCTION

KNOWLEDGE on growth is of importance in understanding the age structure of the population, the conditions under which optimum growth is attained and the influences of various environmental factors on growth. A study of growth in tropical gastropods in general and especially of potamidid snails in particular is very much needed. Among these snails, age and growth studies have been carried out on *Pyrazus palustris* (Rao, 1938), *Cerithidea* (*Cerithideopsilla*) *cingulata* (Sadasivan, 1947,

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1948; Ramamoorthi and Alagaraja, 1969; Vohra, 1970), *C. decollata* (Cockcroft and Forbes, 1981) and on *C. califronica* (Race, 1982).

Presently, absolute and relative growth as well as isometric growth among body parts, and also the allometric growth of *C. (C). cingulata* have been studied since such detailed information on this species is not so far available.

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Material and Methods

Growth of *C. (C.) cingulata* was estimated by three methods. Firsly, population sampling or length frequency method as described by Peterson (1891) and adapted by Graham and Fretter (1947) was employed. Samples for this study were collected from three sites, *viz.*, from Buckingham Canal, river mouth of Vellar and from mangrove area near Pichavaram, located in Vellar-Coleroon estuarine system and pooled. These sites covered the gradient zone, marine and backwater zone respectively. The period of observations extended from September 1982 to August 1984, covering a period of two years. Length of shell was measured with a vernier caliper nearest to 0.1 mm. Shells with wornout upper whorls and broken lips were rejected and normally such specimens comprised only 1% in every collection. They were sorted into various size groups (1.0 mm to 1.9 mm as 1 mm group, 2.0 to 2.9 mm as 2 mm group and so on) and percentage frequency of their occurrence was drawn for each month. The model groups in the above figures were utilised to study growth progression.

The probability plot method (Harding, 1949; Cassie, 1954) of separating the polymodal length frequency distribution using a semilog paper was employed to study the age structure of *C. (C.) cingulata* populations.

Growth of *C. (C.) cingulata* was estimated by directly observing growth in the field. For this purpose, 1,200 specimens, mainly of 8 mm length group (except a few 7 and 9 mm) were used, because the modal group of the snails was about 8 mm length at the time of starting this study. Since numbering was not possible, the snails were marked with white enamel paint on the upper half of the shells. They were released in the estuary on 28-1-1983 and were remeasured on 28th of every following month. The snails were painted again with the same colour after measuring and were returned to the same site of collection. This observation was carried out for a period of 8 months (till August 1983), by which time the snails got dispersed and lost, making it difficult to trace them. Mean shell length was utilised to study the gowth of the snails.

Morphometry of the following characters was considered for which linear measurements were taken as shown in Fig. 1.

1. *Length*: The greatest measurement in dorso-ventral axis.

2. *Maximum width*: The greatest measurement of the body whorl horizontally.

3. *Columellar height*: Greatest measurement in dorso-ventral axis from top of nuclear whorl to columellar base.

4. *Height of body whorl*: Greatest measurement of body whorl along dorso-ventral axis.

5. *Width of oral aperture*: Greatest measurement in horizontal axis from parietal to outer lip.

6. *Length of oral aperture*: Greatest measurement from outer lip to floor of lip.

7. *Diameter of the operculum*: Greatest measurement horizontally.

8. *Length of hump or varix of the body whorl*: This hump, found only in mature snails, was measured along dorso-ventral axis.

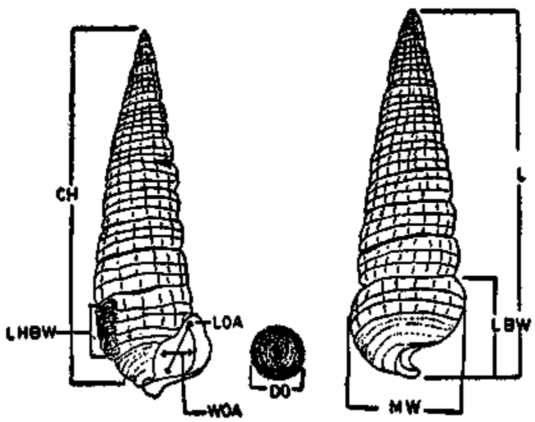

FIG. 1. Measurements employed for morphometric characters of *C. (C.) cingulata*. CH: Columellar height; DO: Diameter of operculum; L: Length; LBW: Length of body whorl; LHBW: Length of hump on body whorl; LOA: Length of oral aperture; MW: Maximum width; WOA: Width of oral aperture.

For studying length-weight relationship, the live total weight of the snail was determined after cleaning the shell of adhering encurstations and sediment particles. The weight was taken nearest to 0.1 mg using an electrical balance. The soft parts of the snail were removed, blotted to remove the excess moisture and weighed to record the flesh weight. The sex and stage of matutity of the gonad were recorded for all measured/weighed snails.

RESULTS

Length frequency histograms for the two year period from September 1982 to August 1984 are given in Fig. 2 a, b. A total number of 22,781 specimens were measured during the study period, ranging in size from 1.2 to 39.4 mm.

A careful perusal of data indicates that size frequency distribution was polymodal during all months because of mixing of broods of various year classes. *C (C.) cingulata* spawns from February to October in the Vellar Estuary and spat settlement takes place from March to September. Because of such prolonged breeding, survival of the larvae and growth depend upon factors like food, preferred substratum, optimum salinity and temperature, etc. The spawns of certain months with ambient conditions survives better and grow faster. Broods of such months mixed with those survivors from adverse periods (monsoon months, for example) and show themselves up as distinct modal groups. When such modes are plotted separately for each month (Fig. 3), they tend to assort into year groups or year classes. Thus, in September 1982, there were two modes, one at 2 mm and another at 7 mm. Naturally these must be the products of that season and were termed brood 'C'. These modes move to 3 and 8 mm respectively in October and could be traced upto August 1984, when they reached the size of 22-23 mm. For studying probable growth, growth curves were fitted to represent a typical brood in each year, giving due consideration to the rate of growth of different broods (Fig. 3). From this growth curve, monthly increment in length was traced for a typical brood of each year. For the brood 'C' of 1982, the growth was from 4 mm (in September 1982) to 16 mm (in September 1983) and then to 23 mm (in August 1984), recording a net growth of 19 mm in 23 months. The actual growth however, was 12 mm during first 12 months and 7 mm in the subsequent 11 months. When the growth curves was extrapolated from 4 mm in September 1982 to 0 mm length, June (Summer) could be observed to be the approximate period of origin for brood 'C'. Therefore, from June 1982, the brood attained a size of 13 mm by June 1983 and 22 mm by June 1984, indicating a growth rate of 1.1 mm per month during the first year and 0.75 mm per month during the second year, in spite of faster rate down growth rates among gastropods, leading to differential growth rate between juveniles and adults (Comfort, 1957; Odum and Smalley, 1959; Cockcroft and Forbes, 1981; Shimek, 1983).

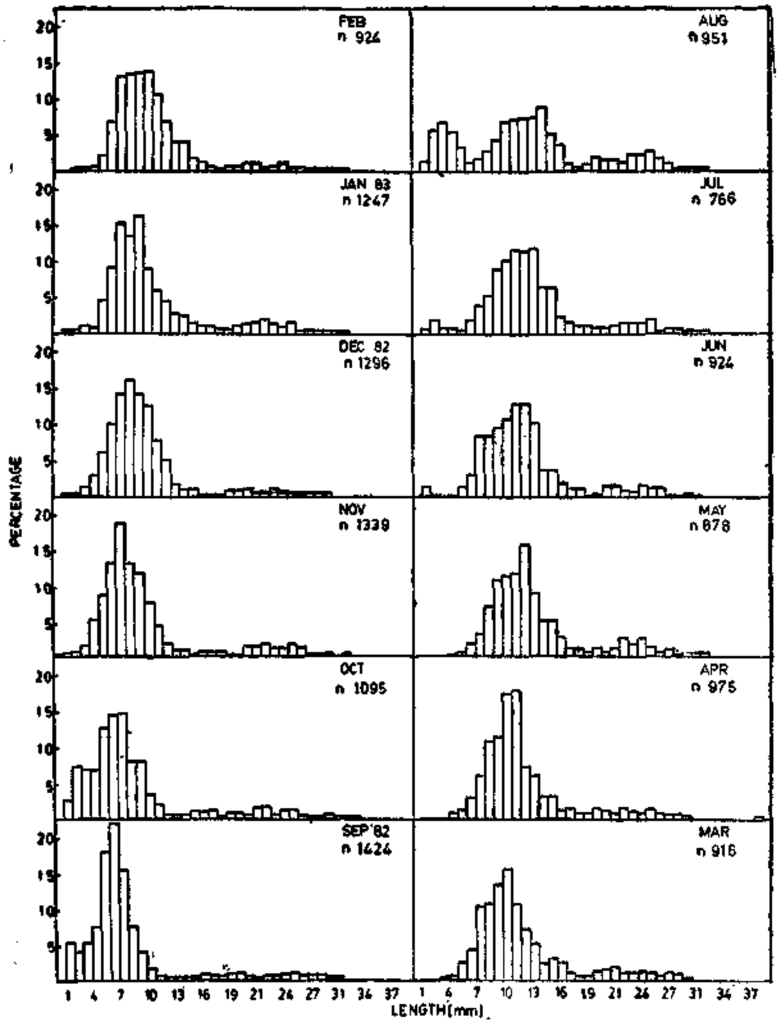

FIG. 2 a. Length frequency of the population of *C.* (*C.*) *cingulata* during 1982-'83 (n = number of specimens examined).

of 1 mm growth per month in the first 6 months. From the length of 19 mm, the growth appears to slow down probably because of the snail attaining maturity. Diversion of energy for maturation and spawning always tend to slow

Growth curves were also drawn for brood 'B' of 1983 and 'A' of 1984. In the case of brood 'B', the growth rate was 13 mm from May 1983 to May 1984 and 16 mm by August 1984 showing a similar trend to that of 'C'. For brood 'A' the growth rate was 7 mm in 5 months from April to August 1984. It is interesting to note that June was the origin of the typical brood in 1982, May in 1983 and April in 1984, all of which are *cingulata* were observed only during these months.

A significant feature observed in 1983 year class was that it was unimodal during most

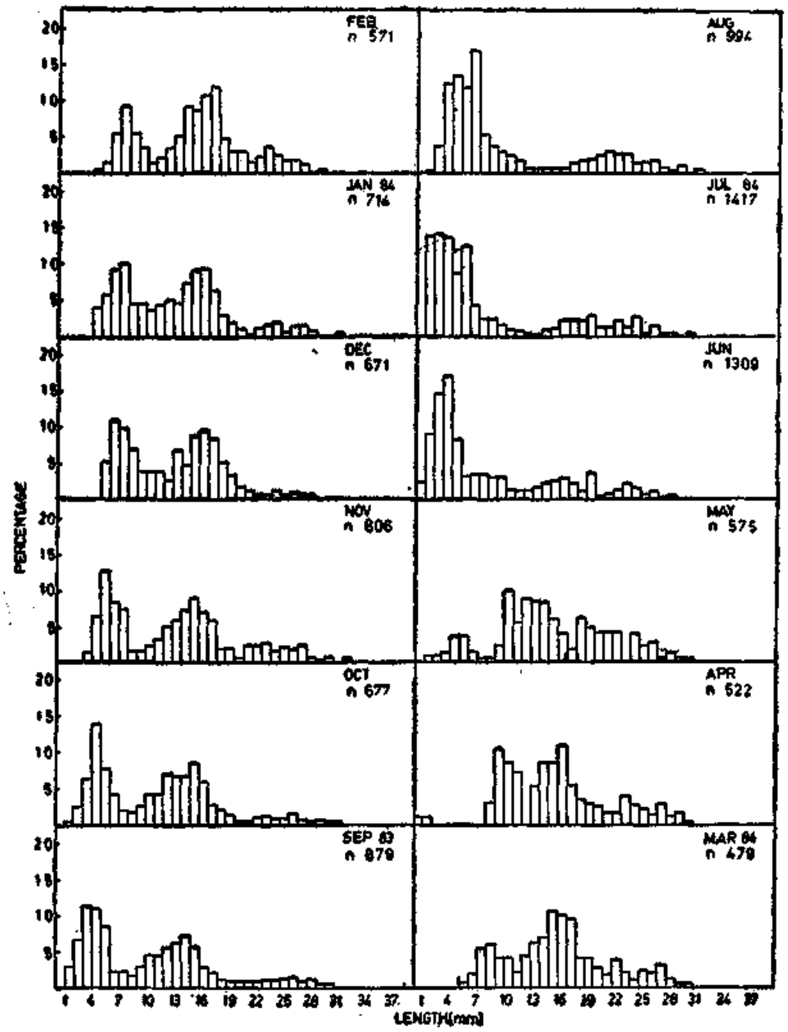

FIG. 2 b. Length frequency of the population of *C.* (*C.*) *cingulata* during 1983-'84 (*n* = number of specimens examined).

typical summer months, when more stable environmental conditions prevail in the estuary. The above observations were further confirmed by the author's observations that largest number of veliger larvae of *C.* (*C.*) of the period, indicating the emergence of brood settled at one particular period, when conditions were optimum. It can also be inferred that unfavourable conditions might have prevailed during rest of the breeding period of that year preventing the emergence of any other broods. This probably resulted in poor recruitment to 1983 year-class and it could be recorded only in very low percentage in the subsequent year, *i.e.*, 1984. On the other hand, the brood 'C' of 1982 was observed to go strong even in 1984. It may be relevant here to mention that 1982 was a severe drought year for whole of Tamil Nadu. Such drought years were observed to result in poor recruitment to shrimp population in Casamanca Estuary, Senegal (Marius, 1976; Le Reste, 1980). Marius (1976) stated that the effect of a hard dry season could be felt on the shrimp populations for several subsequent years. Le Reste (1980) found a correlation between the rainfall of a particular year and catches of shrimps in the subsequent years and recorded that years of low rainfall were always followed by poor catches. While favourable monsoon seasons tend to create ideal conditions for higher recruitment of various populations, adverse monsoon seasons appear to result in uncongenial conditions such as closure of barmouth, low mixing, less flushing and poor replenishment of nutrients from land run off, which result in poor recruitment. It can be concluded that poor recruitment of *C.* (*C.*) *cingulata* population in 1983, might be the result of severe drought and poor rainfall in the catchment areas of Vellar.

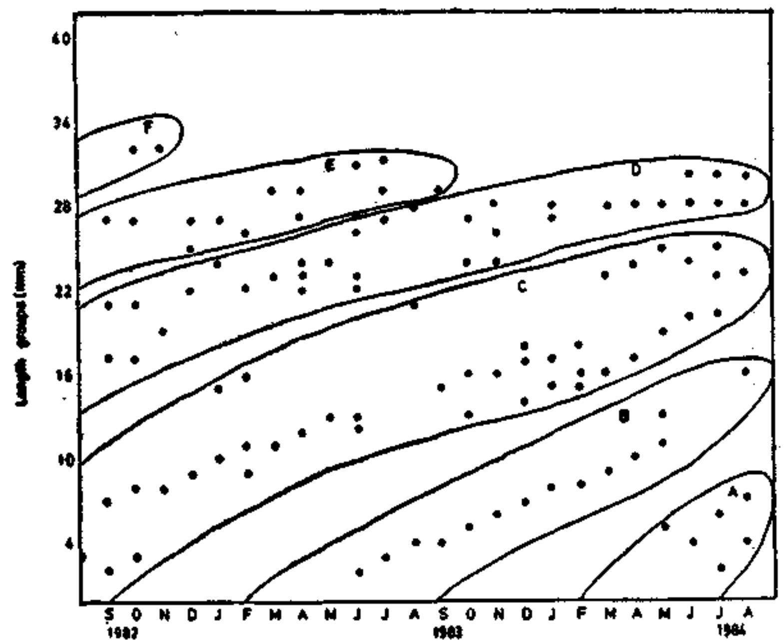

FIG. 3. Modal values of broods of *C.* (*C.*) *cingulata* (A to F) in different months.

Though the growth of younger broods could be traced with ease, it was difficult in the case of older size groups. Slow growth rate and mixing of successive year classes tend to make growth estimations erroneous. However, assorting of modal groups helped in tracing the growth. Taking into consideration the brood 'C', the modal groups at 17 and 21 mm in August 1982, can be safely assumed as the spawn of 1981 (labelled as brood 'D'). Subsequently, the modes shifted to 19 mm in November, 21 mm in December and to 28 and

30 mm in June, July and August 1984. Growth curve indicated a growth of 7 mm (from 19 to 26 mm) in the first 12 months and of 4 mm (from 26 to 30 mm) in the second 11 months, with a growth rate of 0.58 and 0.36 mm per month respectively. The brood with a modal size of 19 mm at September 1982 might have originated during March 1981, attaining a size of 22 at the end of second year progressing to 28 mm by the end of the third year and to 30 mm by 41 months. The growth pattern of 'D' is thus observed to be similar to that of 'C' during the second year of life.

By comparing the growth rates of broods A to F, a growth curve was drawn for *C. (C.) cingulata*, which was sigmoid (Fig. 5). Estimation of the growth was 13 mm at the end of first year, 22 mm at the end of second, 28 mm at the end of third and 32 mm by the end of fourth year, the net growth being 13, 9, 6 and 4 mm respectively. The rate of growth was 1.08 mm in the first year, 0.75 mm in the second year, 0.50 mm in the third year and 0.33 mm in the fourth year. Because of differences in the month of origin of a brood during each year, the modal size group of each brood is

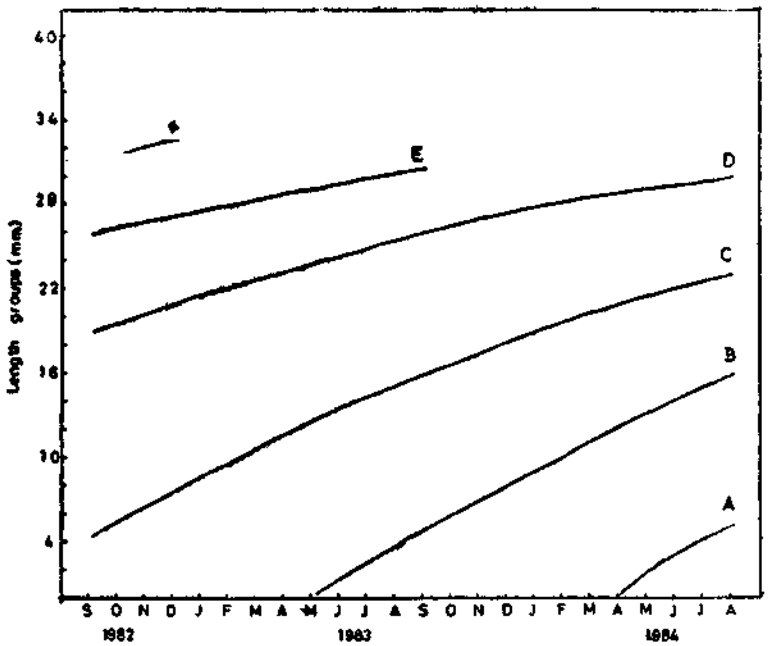

FIG. 4. Growth curves of the broods of *C. (C.) cingulata*.

found to be varying during different months. The life span of *C. (C.) cingulata* appears to be four years under normal circumstances. From an analysis of the data, it is evident that relative growth slowed down after the first year, showing an inverse relationship with actual growth.

Two more broods (E and F) were also discernible during September/October 1982. The former appeared to be the product of 1980 and the latter, that of 1979. Brood 'E' could be traced almost for one year, while 'F' was recorded only in October and November 1982. Brood 'E' showed a growth rate of 5 mm (from 26 mm to 31 mm from September to next September), after which it could not be traced.

Probability plot method

Estimation of growth by this method is advantageous for species with prolonged spawning season. Certain year classes not represented in samples collected and overlapping of distribution of older size groups often tend to influence the estimation of age by length frequency method. Some of these errors are minimised, if this method is employed, since composition of various size groups during the whole year can be utilised here.

tion sampling during the first two years, but was found to be similar during the next two years.

Marking and recovery

Results on the growth rate studies of *C.* (*C.*) *cingulata* from marking and recovery experiments, are given in Fig. 7, wherein the

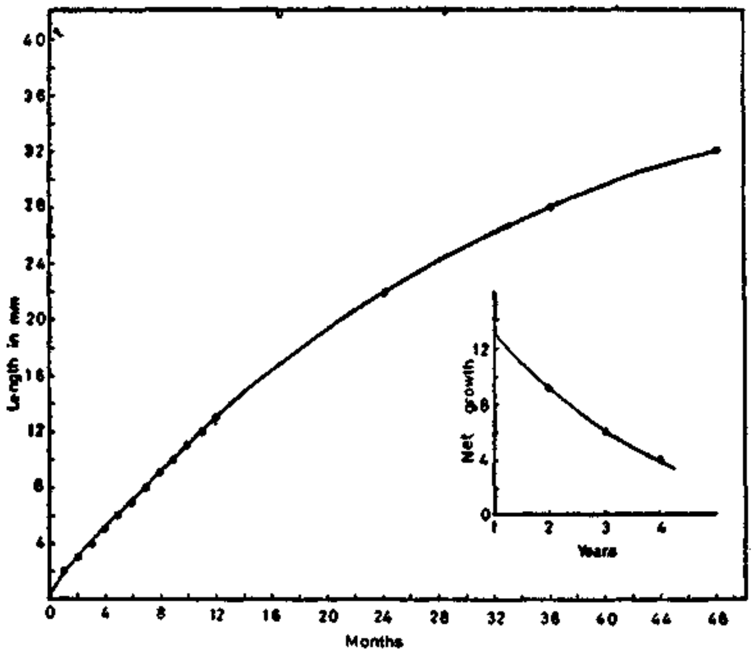

FIG. 5. Growth curve of *C.* (*C.*) *cingulata* (yearly growth is shown in the inset).

Growth curves were plotted separately for 1982-83 and 1983-84 (Fig. 6). Based on the data for 1982-83, the estimated rate of growth was 9.5, 18.5, 26.75 and 32.25 mm at the end of first, second, third and fourth years respectively. Growth curve for 1983-84 also showed that the growth was 9.75, 19.0, 26.5 and 30.5 mm in the consecutive years. Considering the above two observations, the estimated average growth was 9.62, 18.75, 26.62 and 31.37 mm, the relative growth being 9.62 9.13, 7.87 and 4.75 mm in the successive years. Estimated growth from the probability plot method showed slight difference from popula-

length range, number of animals measured and the mean size are indicated. At the beginning of the study in January 1983, the snails ranged between 7 and 9 mm in length, and this was observed to increase to 11 mm and 17 mm in June, indicating differential growth between individuals. However, the mean increment in length was gradual from an initial mean length of 8.2 mm in January to 9.6 mm in February, 10.8 mm in March, 12.0 mm in April, 13.1 mm in May, 14.2 mm in June, 14.9 mm in July and 15.5 mm in August. Taking into consideration the growth rate observed from January to June (since the samples in July and August were meagre), the actual increment was 6 mm in five months (from 8.2 mm to 14.2 mm) at the rate of 1.2 mm per month. It is of significant that the growth estimated from length frequency method was similar to the present one, giving evidence to the earlier conclusions.

$L_t + 1$ against L_t graph, on intersecting by 45° diagonal from the origin, the $L\infty$ value was found to be 42.0 mm. Maximum size of the snail collected during the period of observation was 39.4 (the largest size known for this species, so far), which is fairly close to the above estimate.

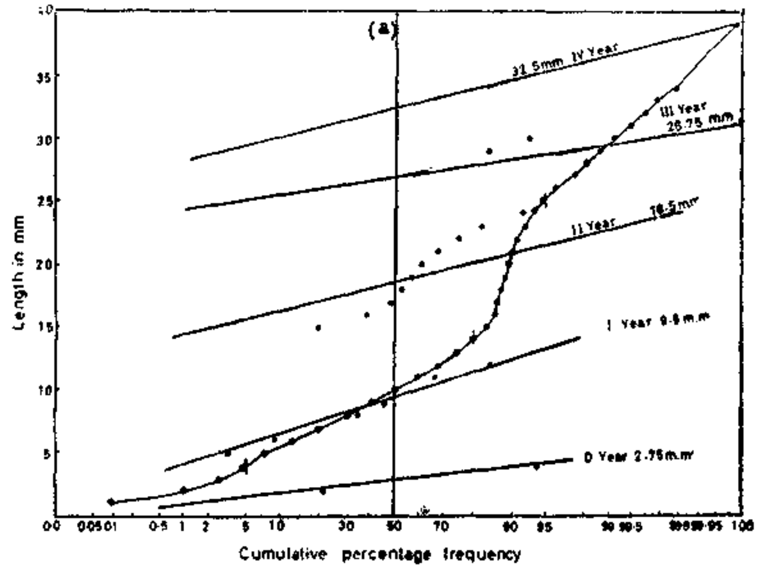

FIG. 6 a. Growth curve of *C.* (*C.*) *cingulata* by probability method for 1982-1983.

Growth parameters

Growth parameters such as the maximum size attained ($L\infty$), the katabolic coefficient (k) and the arbitrary origin of growth curve (t_o) were estimated for *C.* (*C.*) *cingulata*. While the asymptotic length $L\infty$ can be obtained both by Walford graph and von Bertalanffy's equation, the other parameters have to be deduced from the latter equation only.

Walford graph was constructed for *C.* (*C.*) *cingulata* (Fig. 8) by plotting $L_t + 1$ against L_t, where the L_t is the length of the snail at a particular age. From the straight line obtained by connecting the maximum points from the

The age structure obtained by length frequency method and marking and recovery experiments are very much similar and so the age and corresponding length of *C.* (*C.*) *cingulata* obtained from length frequency method, was utilised for calculation of von Bertalanffy's equation. The various parameters obtained are : $L\infty = 39.99$ mm ; k : 0.4054 and t_o = 0.0977 and the equation is

$$L_t = 39.99 \; [1 - e^{-0.4051 \, (t - 0.0971)}]$$

The theoretical growth curve obtained for *C.* (*C.*) *cingulata* is given in Fig. 9 and both calculated and observed values were very close to each other.

Dimensional relationship of shell and operculum

To study the increments in other shell dimensions and in the operculum in relation to shell length, the simple linear regression equation

$$y = a + bx$$

where x is equal to length, y the variable and a and b constants, employed.

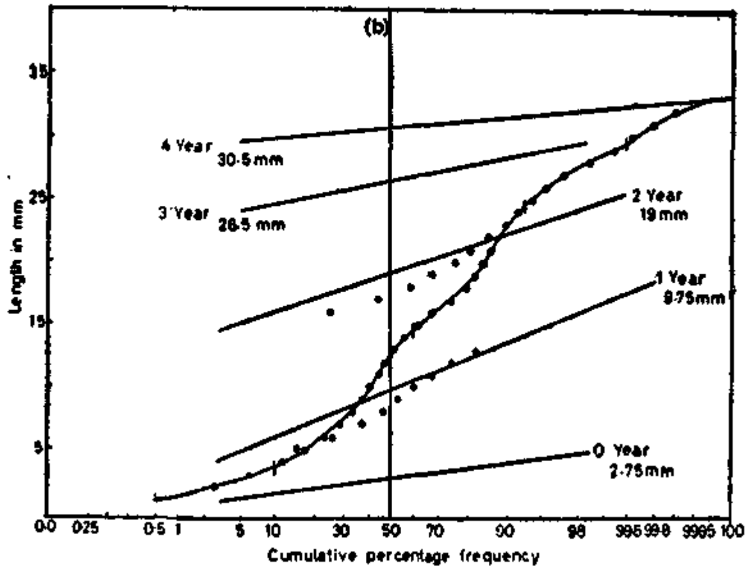

FIG. 6 b. Growth curve of *C. (C.) cingulata* by probability method for 1983-1984.

The results obtained for seven variables, *i.e.*, maximum width, columellar length, length of oral aperture, width of oral aperture, length of body whorl, diameter of operculum and length of hump on the body whorl are given in Table 1 and regression lines in Fig. 10. All the values are highly significant at 0.01% level and the correlation coefficient (r) very close to 1. The relationship is always linear indicating that the variables always grow in proportion to shell length, in smaller to larger individuals. These morphometric relationships can hence be termed as isometric in the case of *C. (C.) cingulata*. Of the seven variables, least growth could be recorded in the case of operculum while maximum increase was observed in the case of columellar length.

Length-weight relationship

The regression lines for total weight and length are given in Fig. 11 a and that for flesh weight and length in Fig. 11 b. They revealed highly significant correlation at 0.01% confidence limit, as the 'r' values were close to 1 (Table 2 and 3).

The data were subjected to analysis of covariance (Snedecor, 1955) and the details for length and total weight, and length and flesh weight are given in Table 4 and 5, respectively. It may be seen from the Tables that mature males and females did not differ significantly from each other, but differed from juveniles in case of total weight and flesh weight in relation to length. Hence common

TABLE 1. *Morphometric relationship between body parts on shell length in* C. (C.) cingulata

Characters		n	b	a	r	p	Significant at
Width	..	128	0.3113	0.8405	0.9841	0.001	0.1%
Columellar height	..	128	0.9628	—0.2743	0.9990	0.001	0.1%
Length of oral aperture	..	128	0.2797	0.3196	0.9823	0.001	0.1%
Width of oral aperture	..	128	0.1864	0.3686	0.9792	0.001	0.1%
Length of body whorl	..	128	0.2673	0.6964	0.9812	0.001	0.1%
Diameter of operculum	..	128	0.1367	0.0017	0.9834	0.001	0.1%
Length of hump on the body whorl	..	55	0.1371	1.3629	0.8591	0.001	0.1%

n = number of specimens, a & b = constants, r = correlation coefficient and p = level of significance.

TABLE 2. *Length-total weight relationship in* C. (C.) cingulata

Group	..	n	b	a	r	p	Significant at
Juvenile	..	64	1.9646	—0.0106	0.8025	0.001	0.1%
Male	..	67	2.6937	—0.7024	0.9847	0.001	0.1%
Female	..	59	2.6334	—0.6272	0.9812	0.001	0.1%

n = number of individuals ; a & b = constants ; r = correlation coefficient ; p = level of significance.

TABLE 3. *Length-flesh weight relationship in* C. (C.) cingulata

Group		n	b	a	r	p	Significant at
Juvenile	..	55	3.2525	—2.3215	0.9656	0.001	0.1%
Male	..	67	2.8309	—1.7645	0.9182	0.001	0.1%
Female	..	59	2.6770	—1.6203	0.8820	0.001	0.1%

n = number of individuals ; a & b = constants ; r = correlation coefficient and p = level of significance.

TABLE 4. *Regression of log total weight on log length in* C. (C.) cingulata (*testing the equality of the regression coefficient 'b' between juvenile, male and female*)

Group	DF	sx^2	sy^2	sxy	DF	s.s.
Juvenile ..	63	2.6812	16.0712	5.2676	62	5.7222
Male ..	66	0.5629	3.9438	1.4196	65	0.1190
Female ..	58	0.6377	4.5938	1.6795	57	0.1705
					184	6.0117
Within groups ..	187	3.8458	24.6088	8.3667	186	6.4067
Variations due to ..	DF	s.s.	m.s.	F	F = ratio (5%-1%)	Significant at (%)
Combined						
Between groups ..	2	0.3950	0.1975	6.04	3.04-4.71	1-5
With in groups ..	184	6.0117	0.0327			
Between juvenile and male						
Between groups ..	1	0.2345	0.2345	5.10	3.92-6.84	+ 5
Within groups ..	127	5.8412	0.0460			
Between juvenile and female						
Between groups ..	1	0.2307	0.2307	4.66	3.92-6.04	5
Within groups ..	119	5.8927	0.0495			
Between male and female						
Between groups ..	1	0.0011	0.0011	2.18	3.92-6.84	Not significant
Within groups ..	122	0.2895	0.0024			

equations for males and females were derived as follows :

Total weight : $\log w = -0.6646 + 2.6575 \log l$

Flesh weight : $\log w = -1.6383 + 2.7151 \log l$

The equations for juveniles are as follows :

Total weight : $\log w = -0.0106 + 1.9646 \log l$

Flesh weight : $\log w = -0.3215 + 3.2525 \log l$

Age composition of the population

The length composition of *C.* (*C.*) *cingulata* during the years 1982-83 and 1983-84, is presented in Fig. 12, which evidences the fact that the population was a mixed one of different ages. In 1982-83, the maximum contribution was by 8 and 10 mm shell length individuals, while 1983-84, 16 mm was predominant. Evidently the former belongs to 0 year class and the latter is 1-year class. This may be due to poor recruitment to the population during 1983-84, as indicated already in an earlier observation. However, when percentage contribution by different length groups of the same year class is combined together, it was observed that 0 year class always dominant over others (Fig. 13). The contribution by 0-year class in 1982-83 was 75.5%, but it was only 51.5%

TABLE 5. *Regression of* log *flesh weight on* log *length in C.* (C.) cingulata (*testing the equality of regression coefficient 'b' between juvenile, male and female*

Group		DF	sx^2	sy^2	sxy	DF	s.s
Juvenile	..	54	1.3841	15.7048	4.5017	53	1.0633
Male	..	66	0.5272	5.0149	1.4924	65	0.7902
Female	..	58	0.6377	5.8752	1.7074	57	1.3037
						175	3.1572
Within groups	..	178	2.5490	26.5949	7.7015	177	3.3257

Variations due to		DF	s.s.	m.s.	F	F = ratio (5%-1%)	Significant at (%)
Combined							
Between groups	..	2	0.1658	0.0843	4.66	3.06-4.75	1
Within groups		175	[3.1572	0.0181			
Between juvenile and male							
Between groups	..	1	0.0679	0.0679	4.32	3.92-6.84	5
Within groups		118	1.8535	0.0157			
Between juvenile and female							
Between groups	..	1	0.1444	0.1444	6.72	3.92-6.84	5
Within groups	..	110	2.3670	0.0215			
Between male and female							
Between groups	..	1	0.0068	0.0068	2.53	3.92-6.84	Not significant
Within groups	..	122	2.0939	0.0172			

in 1983-84. This again evidences the poor entry of new broods to the population during 1983-84.

There is also a gradual decline in the percentage composition by various year classes in subsequent years. Thus the 0-year class of 1982-83 declined from 75.5 to 37.3% in 1983-84; 1 year class of 1982-83 from 16.2 to 10.1% in the next year; 2-year class of 1982-83 from 7.0 to 1.3%, while 3-year class was either negligible or totally disappeared in the subsequent year.

DISCUSSION

Regarding *C.* (*C.*) *cingulata*, observations by Sadasivan (1947) indicated that growth was faster in younger snails, which attained 10 mm shell length size within 7 months, based on field observations and laboratory rearing. He estimated a growth of 22 mm in 19 months and 26 mm in 36 months in Adyar Estuary, Madras. On the maximum size of the species, he stated that only a few shells of 26 mm and exceptionally 30 mm shell length could be collected. He attributed this to the very slow or reduced growth rate after 22 mm when the snail attained maturity. Based on his observations, he also suggested that the longevity of the snail as around 5½ years.

Ramamoorthi and Alagaraja (1969), based on their preliminary observations on *C.* (*C.*) *cingulata* in the Vellar Estuary, concluded that this snail grew 1 mm in each month in younger stages.

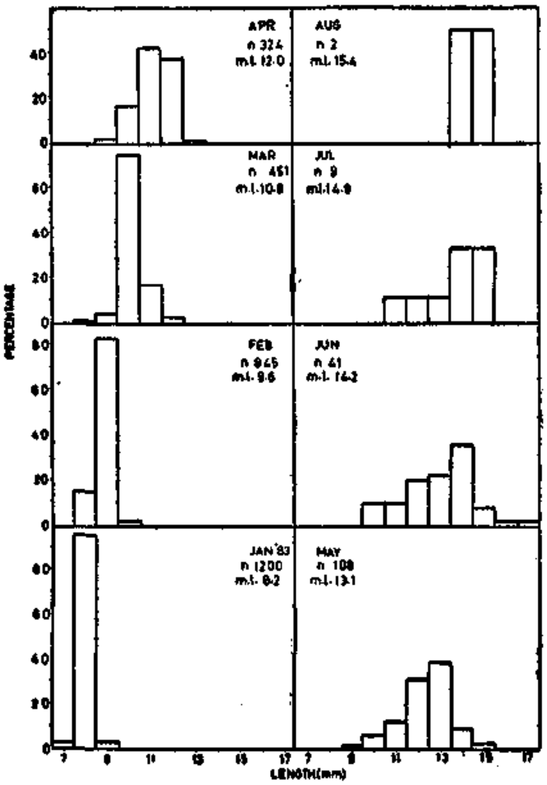

FIG. 7. Length frequency of marked and recovered specimens of *C.* (*C.*) *cingulata* (n = number of specimens; m.l. = mean length).

Vohra (1970), who studied populations of *C.* (*C.*) *cingulata* in Singapore Beach, observed a growth of 8 mm in 12 months. He also stated that growth was fast upto 1.35 mm during the first 6 months, 0.95 mm in the next three months and 0.6 mm in the last three months. He recorded 17 mm as the largest size in the population.

The present observations showed similar results to that of Ramamoorthi and Alagaraja (1969) in that growth was 1 mm during each month in younger snails, but differed slightly from estimates of Sadasivam (1947) and Vohra (1970)—in that growth was slower than that of Madras population and more than that of Singapore population. Moreover, in the present observation, the rate of growth was more steady upto 18th month, when the snail reached the length of 19 mm and slowed down thereafter. Sadasivan (1947) reported faster growth upto 22 mm, but a very slow growth thereafter, while Vohra (1970) reported faster growth rate for the first six months, becoming slow from there. Snails with shell length of 39.4 mm could be recorded in the present study, but not in previous observations. *C.* (*C.*) *cingulata* seems to exhibit differences in growth rate in different localities, depending upon the environmental conditions prevailing therein.

The estimated longevity of four years for *C.* (*C.*) *cingulata* under normal conditions was not uncommon among gastropods. Comfort (1957) estimated the longevity for a number of gastropods and found to range from one to twenty years. Poore (1972) estimated a longevity of 10 years for *Haliotis iris.* Cockcroft and Forbes (1981) estimated the longevity of *Cerithidea decollata* to be in excess of nine years. Therefore, it is obvious that longevity varies markedly between species to species. The estimated longevity of *C.* (*C.*) *cingulata* falls well within the above ranges mentioned by others.

A variety of factors are known to affect the rate of growth and the ultimate size reached by intertidal gastropods. Many workers have ascribed irregular growth to the availability of food. Underwood (1984) showed positive

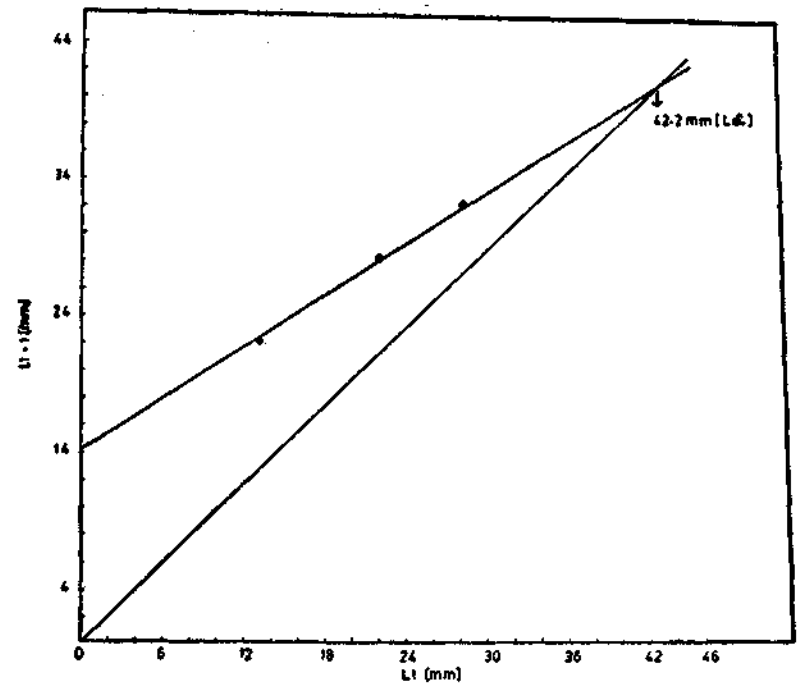

FIG. 8. Walford graph to find out L∞ of *C.* (*C.*) *cingulata.*

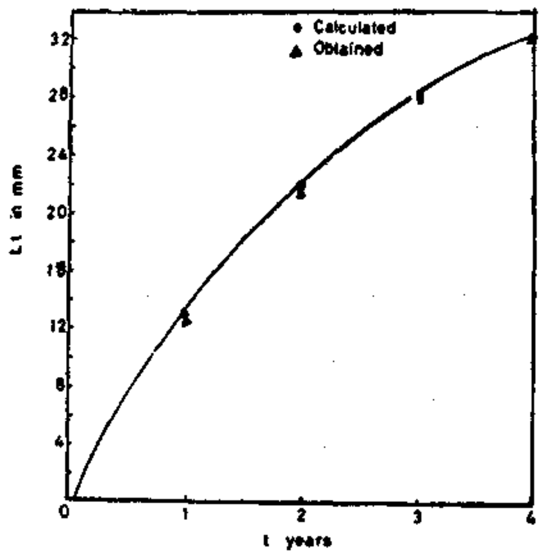

FIG. 9. Von Bertalanffy's growth curve for *C.* (*C.*) *cingulata.*

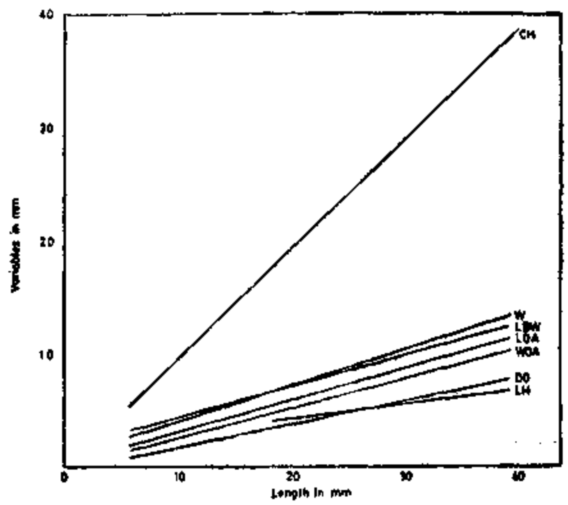

FIG. 10. Dimensional relationship between different parts of shell and its length. CH: Columellar height; DO: Diameter of operculum ; LBW : Length of body whorl ; LH: Length of hump on body whorl ; LOA : Length of oral aperture; W: Maximum width; WOA: Width of oral aperture.

correlation between chlorophyll in the substratum and the rate of growth in *Nerita atramentosa* indicating the availability of food as a major factor for growth. The relatively vigorous growth in *C.* (*C.*) *cingulata* indicates that there is no dearth of food supply in the environment, *i.e.*, Vellar Estuary.

Cellana radiata indicate no seasonal variations in growth pattern in Indian waters. Observations of the earlier workers (Sadasivan, 1947; Ramamoorthi and Alagaraja, 1969) and the present study on *C.* (*C*) *cingulata* also shows that there is no seasonal growth variations.

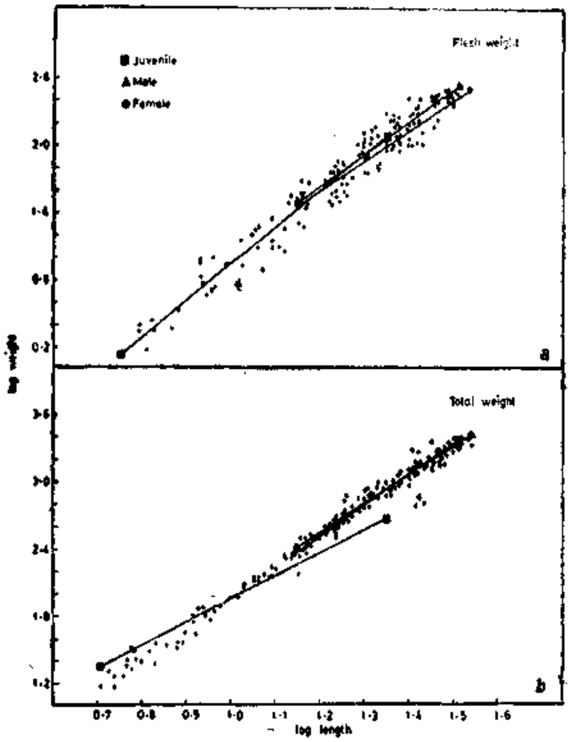

FIG. 11. Length-weight relationship in *C.* (*C.*) *cingulata*: a. between *log* flesh weight and *log* length and b. between *log* total weight and *log* length.

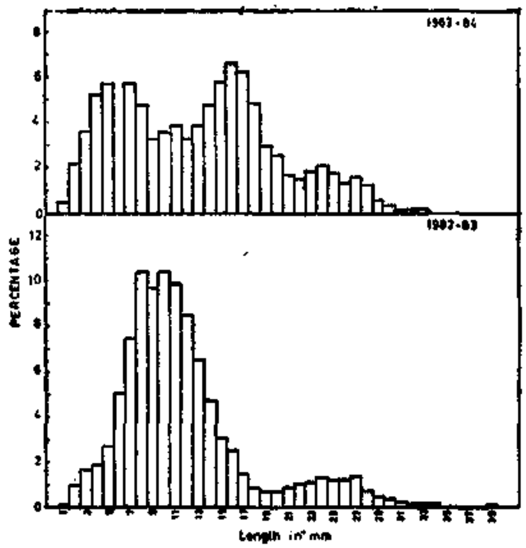

FIG. 12. Length composition of the population of *C.* (*C.*) *cingulata*. During 1982-1983 and 1983-84.

Growth was found to be much faster during summer and slow or absent in temperate waters in general (Graham and Fretter, 1947; Vohra, 1970; Poore, 1972; Cockcroft and Forbes, 1981). It has already been well established that in tropical waters, the animals are subjected to high temperature and show increased initial growth, precocious maturity and intense spawning (Neylor, 1965). Observations by Balaparameswara Rao (1976) on

Forbes and Crompton (1962) found that higher the density the populations, smaller the size. Schalie and Davis (1965) observed greater mortality, stunting and suppression of sexual maturity in larger concentration of *Oncomelania* sp. Reduced population densities tend to induce higher rate of growth as observed by Sutherland (1970) and Haven (1977) in the case of *Acmaea scabra* and by Underwood (1976) in the case of *Nerita atramentosa*. Overcrowding results in accumulation of metabolic wastes, decreased food supply and greater scope for infection, all of which

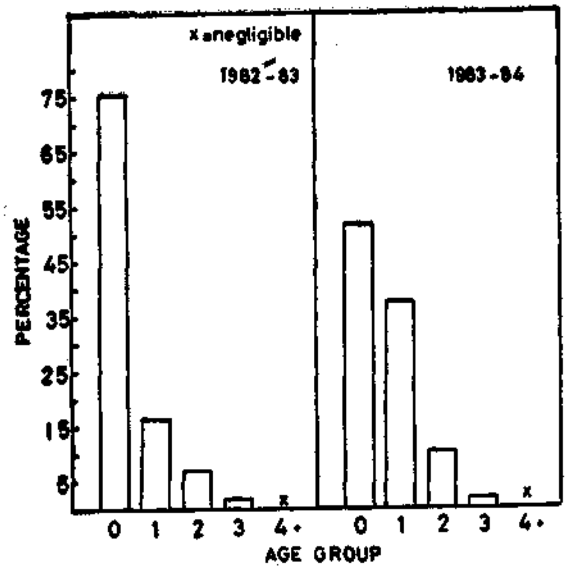

FIG. 13. Percentage composition of different year classes in the population of *C. (C.) cingulata* during 1982-'83 and 1983-'84.

invariably affect the population. However, in an open estuary where ample space is available and where the tidal flushing replenishes the water and brings more food materials, the effect of overcrowding may be minimal. This can be the reason for the steady growth of *C. (C.) cingulata* in the Vellar Estuary.

The relative growth of the body parts in relation to shell length is gradual and isometric. The shell becomes broader when length, breadth and width of the oral aperture are increased; the height of the body whorl and the hump on the body whorl and the operculum increase in size proportionately to the length of the shell. In this aspect, *C. (C.) cingulata* resembles the limpet *Cellana radiata* (Balaparameswara Rao, 1976).

On the other hand, an allometric relationship was found in length-weight relationship, between juveniles and adults, both in the case of total weight and flesh weight. This variations could be attributed to sexual maturity, and also be due to increase in size.

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