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OBSERVATIONS ON THE RATE OF GROWTH, SEXUAL MATURITY AND BREEDING OF FOUR SEDENTARY ORGANISMS FROM THE MADRAS HARBOUR*

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INTRODUCTION

THE destruction caused to the underwater harbour installations and ships' bottom by the accumulation of sedentary organisms drew the attention of workers in temperate and subtropical regions to a study of the biology and ecology of such animals as a preliminary step in tackling the antifouling problem. It has been observed under tropical conditions that fouling is more pronounced due to prolonged period of breeding activity, settlement in larger numbers and constant organic growth (Edmondson, 1944 ; Pyefinch, 1947 ; Daniel, 1954). A fact-finding survey to determine the members of the fouling community, their abundance in relation to different environmental conditions, seasonal or ecological succession, if any, their rate of growth and breeding activities will contribute much towards an understanding of the fouling problem. In an earlier paper the author (Antony Raja, 1959) has dealt with the distribution and succession of sedentary organisms of the Madras harbour with a discussion on the influence of environmental factors. Except for a preliminary survey of marine borers of the Cochin harbour (Erlanson, 1936), observations on the growth of a few sedentary organisms of the Madras harbour (Paul, 1942) and brief records from the Vizakhapatnam harbour (Ganapati *et al.*, 1958), information regarding the growth rate of marine sedentary organisms of sheltered waters is not available. Hence an attempt is made here to estimate the rate of growth, size at sexual maturity and breeding of four sedentary organisms, namely, *Modiolus striatulus*, *Bowerbankia* sp., *Cynthia* sp., and *Dasychone cingulata* as a continuation of Paul's work, which has not dealt with the above forms.

METHODS

Observations on growth rate were centred at three stations of the Madras harbour, namely, New North Quay, Boat Basin and Canal. The location and characteristics of these stations are given in the author's previous paper (*op. cit.*). Records of growth of the animals which settled on teak planks of $10'' \times 8'' \times \frac{1}{2}''$ size suspended in water from February 1954 to February 1955 were maintained. The individuals were marked out as soon as they were visible to the naked eye after attachment and readings were taken periodically. Other sedentary organisms were scraped off whenever necessary to leave the marked individuals quite distinct. The data collected in this way were compiled and the growth rate was recorded as mean increase in length for every ten days interval. While compiling the data, taken during all the months of the observation period, care was taken to see whether there was any differential growth in the individuals during different months. Since it was observed that there were no appreciable differences in the growth of those settled in months other than in October, the data relating to all the months except

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October were pooled together before striking at the average. The age in all cases denotes the length of life of the particular organism after attachment. The values of means were corrected to the nearest whole or 0.5 mm.

In view of practical difficulties in following the growth of marked individuals continuously for more than four or five months, growth was also studied with the help of random samples drawn from a population of organisms periodically from October 1953 to February 1955. The substrata selected for such a study were the concrete pillars of New North Quay, a condemned launch at Boat Basin and the side walls of Canal. After initially scraping clean these sites, monthly once the average size of usually not less than 25 individuals that were found on an area of about 80 to 120 sq. inches was recorded. The records taken by this method were used in comparing the results obtained from marked individuals.

The growth rate of the organisms at the different depths was studied at Boat Basin by suspending planks at different levels below low water mark, namely, 1′, 3′, 5′, 7′, 9′ and 12′ as well as 2′ above low water mark. The data obtained through this helped to determine the optimum depth at which the organisms recorded a rapid growth.

The growth of the individuals in the laboratory conditions wa studied with the specimens removed from Boat Basin and reared in glass tanks (16″×11″×11″) having a thick coating of the diatoms, filamentous green and brown algae. Sea water was changed twice daily.

The breeding activity of each species was determined from the bi-weekly settlement on test panels of same dimensions as used for growth study. The number of individuals attached on both the sides of the panels was taken into consideration for this purpose and also occurrence of larvae in plankton.

Observations

(a) *Modiolus striatulus* Hanley

Growth

From marked individuals.

TABLE 1

A record of rate of growth in length in mm. at the three stations

Age (Days)	Boat Basin		New North Quay		Canal	
	Mean length	Increase in length	Mean length	Increase in length	Mean length	Increase in length
10	4.5	..	4.0	..	3.0	..
20	7.0	2.5	7.0	3.0	4.5	1.5
30	9.0	2.0	8.5	1.5	5.5	1.0
40	11.5	2.5	11.0	2.5	7.0	2.0
50	12.0	0.5	12.5	1.5	8.5	1.5
60	12.5	0.5	13.0	0.5	9.5	1.0
70	13.0	0.5	13.0	..	11.0	1.5
80	14.5	1.5	14.5	1.5	12.5	1.5
90	16.0	1.5	16.0	1.5	14.0	1.5
100	17.0	1.0	17.0	1.0	15.0	1.0
110	18.5	1.5	18.5	1.5	15.0	..
120	19.5	1.0	18.5	..	15.5	0.5
130	20.0	0.5	18.5	..	16.0	0.5
140	20.0	..	18.5	..	17.0	1.0
150	20.0	..	18.5	..	17.0	..

The average growth record (Table I) shows that the growth in the initial period of about 40 days is very fast at Boat Basin and Quay, when the individuals record 11.5 and 11.0 mm. respectively which is almost 55 to 60% of their total growth in five months after which, the growth is progressively slow. Moreover, for the first four months there is a close similarity in the growth records at both the stations. The growth at Canal is very slow compared to the other stations although the final size obtained at the end of five months closely approximates to that registered at Quay.

As stated earlier, growth of mussels that settled in October was studied separately. It is seen that during October to January the individuals record at the end of 30, 60, 90 and 120 days, 6.5, 11.0, 15.5 and 19.5 mm. respectively at Basin, 8.5, 13.0, 16.0 and 18.5 mm. at Quay and 4.0, 8.5, 13.0 and 15.0 mm. at Canal. A perusal of records taken during other months (*vide* Table I) shows that at the end of corresponding periods the individuals at Basin record 9.0, 12.5, 16.0 and 19.5 mm., those at Quay, 8.5, 13.0, 16.0 and 18.5 mm. and those at Canal 5.5, 9.5, 14.0 and 15.5 mm. A comparison of the above two sets of readings show that during October growth is markedly affected at Basin and Canal and not at Quay. However, the total growth during 120 days does not seem to be affected by the initial stunted growth of the first 30 days, for, it is seen that at the end of 120 days the sizes attained by October settled individuals are more or less the same as those recorded by individuals settled during other months.

From random samples.

TABLE II

A record of mean growth in mm. from random samples

Boat Basin			New North Quay			Canal		
Date of observation	No.	Mean length	Date of observation	No.	Mean length	Date of observation	No.	Mean length
13-10-'53	75	8.0	22-2-'54	79	7.0	18-1-'54	53	4.0
18-11-'53	63	11.0	22-3-'54	70	12.0	22-2-'54	50	8.0
14-12-'53	59	13.0	19-4-'54	73	13.5	22-3-'54	52	12.0
11-1-'54	67	16.0	21-6-'54	69	18.5	19-4-'54	39	15.5
15-2-'54	61	20.0	19-7-'54	75	19.0	19-6-'54	40	18.0
22-3-'54	53	20.0	16-8-'54	70	20.0	19-7-'54	37	18.5
19-4-'54	45	20.0	20-9-'54	63	20.0	16-8-'54	39	18.5
21-6-'54	40	21.0	18-10-'54	49	20.5	13-9-'54	33	18.5
19-7-'54	40	21.0	15-11-'54	45	20.5	11-10-'54	29	19.0
16-8-'54	42	21.0	20-12-'54	40	21.0	22-11-'54	27	19.5
20-9-'54	39	21.0	11-1-'55	31	21.0	20-12-'54	29	19.5

The readings taken on population samples from October 1953 to January 1955 (Table II) accord generally with the observations made on marked individuals. However, the animals of random samples taken from Basin show a decidedly slower growth than marked individuals during the first month, for, the mussels with an initial mean length of 8 mm. show an increase of only 3 mm. in 35 days while marked individuals of about the same length register an increase of 5 mm. in 30 days only. Similar difference is seen after two months of growth also. It is tempting to ascribe this to some factor like crowding but since such a decreased growth rate is not seen at Quay and Canal, it can be ruled out. As will be discussed later, this retarded growth appears to be due to the lowering of salinity in October which might have affected the young mussels at Basin.

At different depth levels.

TABLE III

A record of mean growth at different depth levels (length in mm.)

(Lwk: Low water mark)

Age	2′ above Lwk	1′ below Lwk	3′ Lwk	5′ Lwk	7′ Lwk	9′ Lwk	12′ Lwk
1 month	6.0	8.5	8.5	9.0	7.5	7.0	4.0
2 months	8.0	11.5	12.0	13.0	10.5	10.5	7.0
3 months	11.0	15.5	16.0	16.5	14.5	14.5	10.5
4 months	14.0	19.0	19.5	20.5	18.5	17.0	12.0

The mean lengths attained by individuals which settled on test panels immersed at different depths for four consecutive months beginning from August are shown in Table 3. It may be seen that the bivalves grow to bigger sizes on panels between 1 and 5′ below low water mark whereas on those suspended at 7 and 9′, growth is comparatively poor. On panels kept at 2′ above low water mark and 12′ below, growth is markedly slower than at any other level.

Under laboratory conditions. Fifty individuals measuring about 5 mm. in length were introduced in the laboratory tanks of which 13 did not survive the whole observational period of three months. The mean length attained by the survivors for ten day intervals up to a period of 90 days were 6.5, 8.0, 10.0, 11.0, 11.5, 12.0, 13.0, 13.5 and 14.0 mm. respectively. Thus, the mussels record 5 mm. in the first month, 2 mm. in the second month and 2 mm. in the third month, recording an increment of 9 mm. showing thereby that under laboratory conditions the animals register growth less than that recorded in Basin and Quay but more or less similar to that of Canal region.

Relative dimensions of the shell at different age levels.

Observations on the mean growth in breadth and height in relation to length (Fig. 1) show that their increase is almost parallel up to about a period, when the mussels attain a length of about 11.0 mm. after which, the increase in breadth is more rapid than that of height. As will be shown later, this differential growth rate almost coincides with the size at sexual maturity.

The ratios between breadth and length (B/L), breadth and height (B/H) and height and length (H/L) are presented in Table IV. There is in general an increase in the B/L ratio up to about 70 days after which there is a decrease in this ratio. Although such a strict regularity could not be noticed in the H/L ratio, it appears to follow the same trend as the previous ratio. However, the B/H ratio fluctuates between 1.17 and 1.33 at Basin and between 1.00 and 1.25 at the other two stations

TABLE IV

A record of mean breadth and height in mm. and the ratios between the different dimensions

(B : Breadth ; L : Length ; H : Height)

Age (days)	Boat Basin					New North Quay					Canal				
	B	H	B/L	B/H	H/L	B	H	B/L	B/H	H/L	B	H	B/L	B/H	H/L
10	2.5	2.0	0.555	1.25	0.444	2.0	2.0	0.500	1.00	0.500	1.5	1.5	0.500	1.00	0.500
20	4.0	3.0	0.571	1.33	0·428	3.5	3.0	0.500	1.17	0.428	2.5	2.0	0.555	1.25	0.444
30	5.5	4.5	0.611	1.22	0.500	4.5	4.0	0.529	1.12	0.470	3.0	2.5	0.545	1.20	0.454
40	7.0	6.0	0.608	1.17	0.522	6.0	5.5	0.545	1.09	0.480	4.0	3.5	0.571	1.14	0.500
50	7.5	6.0	0.625	1.25	0.500	7.0	6.0	0.583	1.17	0.400	5.0	4.0	0.588	1.25	0.470
60	7.5	6.0	0.600	1.25	0.520	7.5	6.0	0.574	1.25	0.461	5.5	4.5	0.577	1.22	0.473
70	8.0	6.5	0.625	1.23	0.500	7.5	6.0	0.574	1.25	0.461	6.5	5.5	0.591	1.18	0.500
80	8.5	6.5	0.586	1.30	0.448	8.0	6.5	0.552	1.23	0.448	7.5	6.0	0.560	1.25	0.480
90	8.5	6.5	0.531	1.30	0.406	8.0	6.5	0.500	1.23	0.406	7.5	6.0	0.535	1.25	0.428
100	9.0	7.5	0.529	1.33	0.441	8.5	7.0	0.500	1.21	0.412	8.0	6.5	0.533	1.25	0.433
110	9.5	8.0	0.513	1.19	0.432	9.0	7.5	0.485	1.20	0.405	8.0	6.5	0.533	1.25	0.433
120	10.0	8.0	0.513	1.25	0.410	9.0	8.0	0.485	1.13	0.432	8.0	7.0	0.516	1.14	0.451
130	10.0	8.5	0.500	1.17	0.425	9.0	8.0	0.485	1.13	0.432	8.0	7.0	0.500	1.14	0.437
140	10.0	8.5	0.500	1.17	0.425	9.0	8.0	0.485	1.13	0.432	8.0	7.0	0.471	1.14	0.412

and there is no definite correlation between this ratio and age. Comparing all the three ratios, it is seen that, when there is a decrease in the ratio of height-length, there is a corresponding increase in the other two ratios at the age of 20 days and

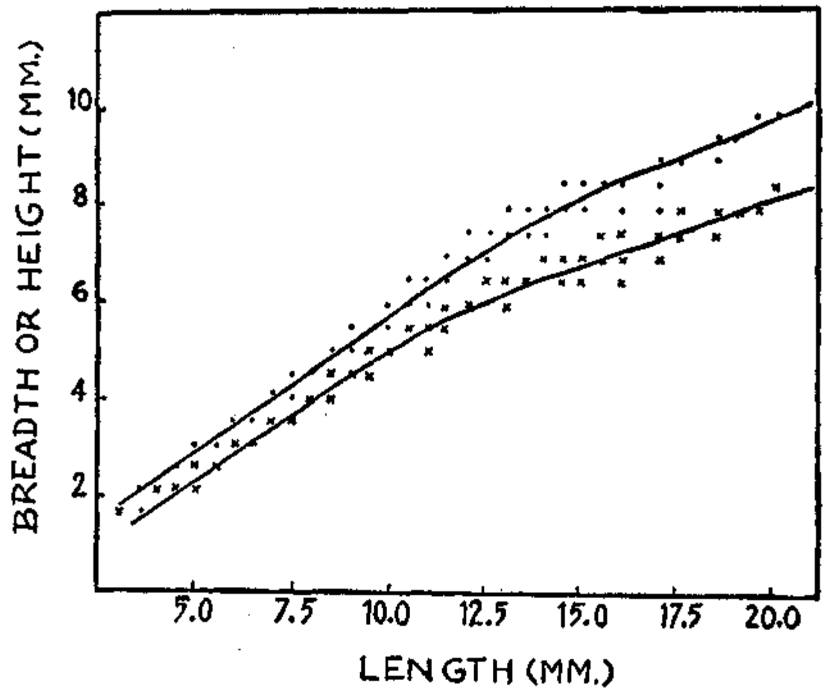

FIG. 1. The mean values of breadth (dots) and height (crosses) in relation to length.

50 days. Also, when the ratio of breadth-height falls during 20 to 40 days, there is a corresponding rise in the other two ratios. Similarly, when the ratio of breadth-height rises during 70 to 100 days, the other two fall.

Sexual maturity and breeding

Examination of the gonads of individuals between 5 and 20 mm. in length has shown that gonadial follicles appear after the mussel reaches 6.5 to 7.5 mm., *i.e.* at the age of about 20 days. The ripe gonads are found in 10 to 11 mm. individuals which under natural normal conditions is attained in 30 to 40 days. The mantle of a sexually mature male is cream coloured and that of a female orange. Throughout the year individuals have mature gonads but as shown by the poor settlement of young spats in winter months (*vide* infra), the breeding appears to slacken during that period.

It is seen from Fig. 2 that after a poor settlement during December to January, there is a steady increase in the attachment of spat in later part of February and the number of spat reaches the maximum during the last week of March after which, the settlement slowly declines till June. Again it rises and in the first week of August there is another peak followed by a sudden drop in September to December. During early January the settlement is least. Judging by the size of the spat (about 3 m.m. which may be attained in six or seven days after the settlement of the larvae) and the large number of veligers in the plankton, it can be said that the peak of breeding activity is in March-April and in July-August.

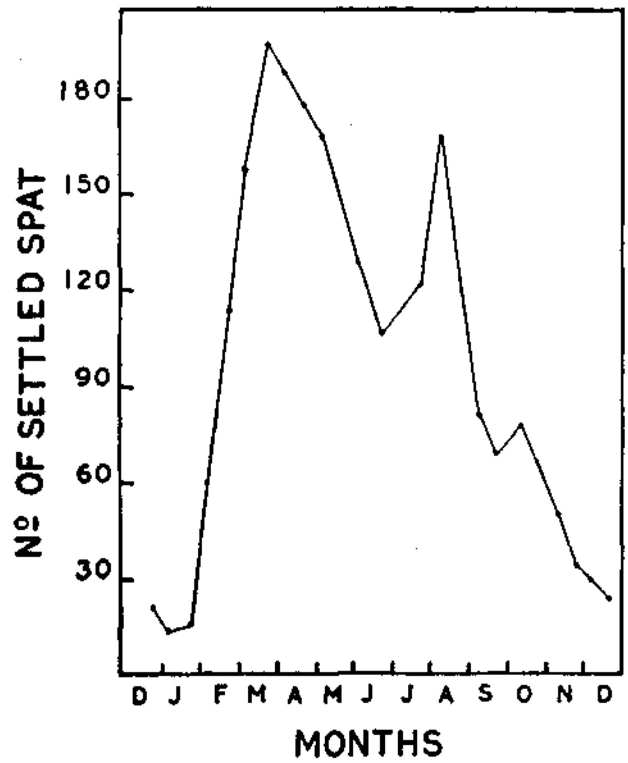

FIG. 2. The bi-weekly settlement of *M. striatulus.*

(b) ***Bowerbankia*** sp.

After the larvae settle, they attach themselves to the substratum by the broadening of the base into a disc-like structure Further growth ensues rapidly by budding, resulting in the production of an erect colony.

Growth

From marked individuals.—Though growth records on both length and breadth of the colonies have been taken, only the growth in length is discussed here. The data on breadth are used to calculate the ratio between the two dimensions. The initial measurement of the colony is 5 mm., in both length and breadth. It is seen from Table V that as much as 59% at Basin, 53% at Quay and 67% at Canal of total growth in four months are recorded in the first month itself, the second month adding roughly 20 to 25%. Though the maximum size attained at the Canal is the least, the colonies of this station grow a little faster than those of Quay for the first 40 days. During the next 40 days, the increase in length at these two stations is more or less similar and only after about three months, the Quay colonies grow a little faster and attain a slightly greater length than those of Canal. The Boat Basin

Table V

A record of mean growth in length (L) and breadth (B) in mm. and the ratio between the two dimensions

Age (days)	Boat Basin				New North Quay				Canal			
	L	B	Mean increase in length	B/L	L	B	Mean increase in length	B/L	L	B	Mean increase in length	B/L
10	66	51	..	0.773	63	43	..	0.682	62	46	..	0.742
20	102	79	36	0.774	83	58	20	0.698	93	69	31	0.742
30	128	97	26	0.765	100	71	17	0.710	119	87	26	0.731
40	150	110	22	0.753	134	99	34	0.738	137	100	18	0.730
50	171	120	21	0.701	148	106	14	0.716	146	107	9	0.732
60	183	128	12	0.700	150	107	2	0.720	151	110	5	0.728
70	193	134	10	0.694	163	114	13	0.699	162	113	11	0.697
80	202	138	9	0.683	169	117	6	0.692	167	114	5	0.682
90	208	142	6	0.682	175	121	6	0.691	171	117	4	0.684
100	213	144	5	0.676	182	125	7	0.687	176	121	5	0.687
110	215	145	2	0.674	184	126	2	0.684	177	122	1	0.688
120	216	146	1	0.675	187	127	3	0.674	177	122	..	0.688
130	216	146	..	0.675	187	128	..	0.684	177	122	..	0.688

colonies maintain their uninterrupted growth throughout the period and attain the largest size. While the mean increase in length steadily decreases with advancement of age at Basin and more or less a similar pattern is seen at Canal also, the Quay colonies show widely fluctuating increase.

It is also seen from the table that the breadth-length ratio at each age level is variable only within a limited range of 0.1. Both at Basin and Canal the ratio decreases with age. A similar regularity is not seen in the case of Quay individuals. Although the differences in values are not much, yet, as observed earlier, this is due to the fluctuations seen in the growth records at Quay.

Since this species does not settle below 5′ of low water level, observations on its growth under different levels have not been recorded. Also, in view of small number of colonies attaching in limited space, random samples could not be taken.

Under laboratory conditions.—Forty small individual colonies each measuring about 10 mm. in length were removed from Basin and reared in the laboratory. All the colonies survived a period of three months and the mean length obtained at ten day intervals up to 90 days were 65, 90, 112, 127, 140, 143, 147, 147 and 147 mm., respectively. This shows that the growth is more or less similar to that at Canal region up to about 50 days only after which, under laboratory conditions growth is not as fast as at Canal.

Sexual maturity and breeding.

Majority of the colonies examined showed that the ovicells appear when they are 5 to 8 days old and measure 35 to 50 mm., but there were a few colonies which did not have ovicells even when they had reached a length of about 100 mm. It is also interesting to note that such instances were found only in the months of February, March, August and September. This period, as will be shown later, is one when the attachment of the colonies to the test panels was found to be poor. Small colonies kept under laboratory conditions also attained sexual maturity at the same size as those in the natural habitat.

The settlement records taken twice a month during January 1954 to January 1955 (Fig. 3) show a periodicity in spawning. The amount of attachment which is quite high during January slowly falls down to a minimum during March-April but rises again to a maximum in May. This is followed by another steady decline and in September a stage similar to April is noticed. The settlement again shoots up during the following months reaching the peak in December and the cycle is again repeated. Thus, two clear peaks exist in the year round breeding activity of this species, one in December-January and another in May-June and agrees with similar observations on another Polyzoan, *Crisia* sp. (Daniel, 1954).

(c) *Cynthia* sp. (*Pyura*)

In the following account, the increase in length has been taken to represent its growth. The ' length ' denotes the maximum distance from the tip of oral aperture to base and the ' breadth ', the maximum horizontal measurement. While handling, since the siphons are withdrawn and the animal shrinks, all measurements relate only to this condition.

Growth

(i) *From marked individuals.*—It is seen from Table VI that the growth at Quay and Basin is similar but the growth at Canal is comparatively poor. It is also seen that 70% of their total growth of about five months is attained during the first 50

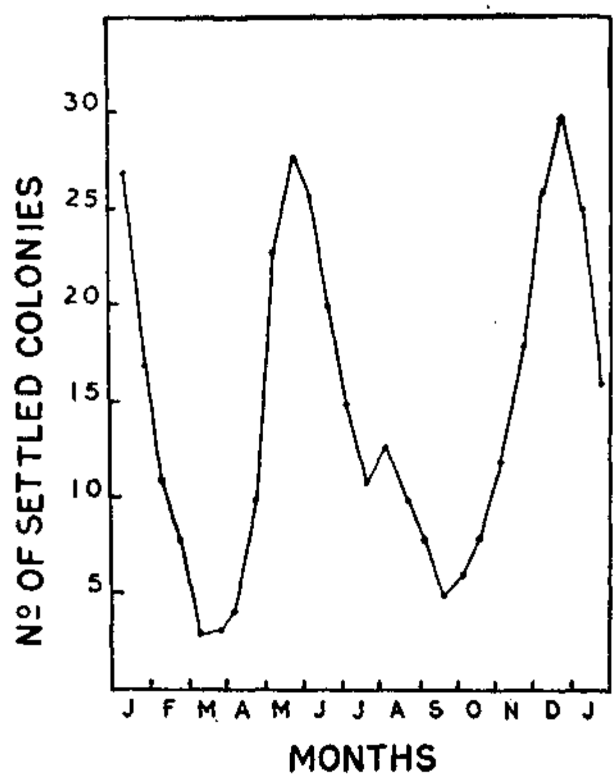

FIG. 3. The bi-weekly settlement of *Bowerbankia* sp.

days, the rest being added in the subsequent 60 to 70 days. In general, it is observed that growth is faster during the first month till the animal attains a length of about 16 to 17 mm. after which, the rate of increase decreases. It is also seen from the table that the breadth-length ratio which ranges between 0.5 and 0.8, increases with age.

It has been pointed out in the case of *M. striatulus* that growth is poor during October due to lowering of salinity consequent on the influx of fresh water at Basin. To see whether such a feature affects this species also, readings were taken on those settled in October, 1954. It is seen that the sizes attained at the end of 30, 60, 90 and 120 days are 11, 17, 23 and 28 mm. at Basin, 15, 21, 26 and 30 mm. at Quay and 7, 14, 19 and 22 mm. at Canal. The records taken during other months (Table VI) show that the respective sizes at the end of corresponding periods are 16, 22, 27 and 29 mm. at Basin, 17, 23, 29 and 30 mm., at Quay and 11, 18, 21 and 23 mm. at Canal. These readings, when compared with those of October-settled individuals, show that both at Basin and Canal there is a marked retardation in growth during October.

TABLE VI

A record of mean growth in length (L) and breadth (B) in mm. and the ratio between the two dimensions

Age (days)	Boat Basin				New North Quay				Canal			
	L	B	Mean increase in length	B/L	L	B	Mean increase in length	B/L	L	B	Mean increase in length	B/L
10	7	4	..	0.571	7	4	..	0.571	5	3	..	0.600
20	12	7	5	0.583	11	7	4	0.636	7	4	2	0.571
30	16	10	4	0.625	17	11	6	0.646	11	7	4	0.636
40	18	12	2	0.666	19	13	2	0.684	14	9	3	0.643
50	20	14	2	0.700	21	14	2	0.666	16	11	2	0.687
60	22	15	2	0.654	23	15	2	0.652	18	12	2	0.666
70	23	17	1	0.739	25	17	2	0.680	19	13	1	0.684
80	25	18	2	0.720	27	19	2	0.704	19	13	..	0.684
90	27	19	2	0.704	27	20	..	0.741	21	14	2	0.666
100	28	20	1	0.714	29	22	2	0.758	21	14	..	0.666
110	29	21	1	0.724	29	23	..	0.793	22	15	1	0.654
120	29	22	..	0.758	30	24	1	0.800	23	16	1	0.699
130	29	23	..	0.793	30	25	..	0.833	23	16	..	0.699
140	29	23	..	0.793	30	25	..	0.833	23	16	..	0.699

However, as seen in *M. striatulus*, the final sizes at the end of 120 days are not much affected by the initial slow growth of first 30 days.

From random samples.—The readings taken on the random samples (Table VII) agree with those taken on marked individuals. In addition to this, the table shows that growth after four months is negligible and the maximum size is attained in as short a period as four months. The largest individuals measure 30 to 31 mm. in length.

TABLE VII

A record of mean growth in mm. from random samples

Boat Basin			New North Quay			Canal		
Date of observation	No.	Mean length	Date of observation	No.	Mean length	Date of observation	No.	Mean length
19-3-54	32	6	19-3-54	35	7	22-2-54	32	6
19-4-54	35	17	19-4-54	38	19	22-3-54	35	15
21-6-54	32	27	21-6-54	51	29	19-4-54	31	19
15-7-54	38	29	15-7-54	47	30	21-6-54	35	23
16-8-54	30	29	16-8-54	41	30	15-7-54	32	23
20-9-54	35	29	29-9-54	37	30	16-8-54	27	23
18-10-54	30	30	18-10-54	35	31	20-9-54	21	24
15-11-54	37	30	15-11-54	21	31	18-10-54	21	24
20-12-54	35	30	20-12-54	30	31	15-11-54	17	24
16-1-55	35	30	16-1-55	27	31	..	..	..
18-2-55	31	30	..	..	..	..	..	..

At different depth levels.

TABLE VIII

A record of mean growth (length in mm.) at different depths

Age	1′	3′	5′	7′	9′
1 month	16	17	16	14	11
2 months	21	22	21	18	14
3 months	28	28	26	22	18
4 months	29	29	27	23	20

The growth record maintained at different depths at Basin at the end of successive one-month periods is given in Table VIII. It is seen that the individuals show maximum growth at 1 to 5′ below low water mark and that below 5′ growth is progressively slower.

Under laboratory conditions.

TABLE IX

A record of mean growth in the laboratory (Initial length : 6 mm.)

Age (days)	Fixed individuals	Free individuals
10	9	8
20	12	10
30	13	11
40	14	11
50	15	11
60	15	12
70	16	12
80	16	12
90	16	12

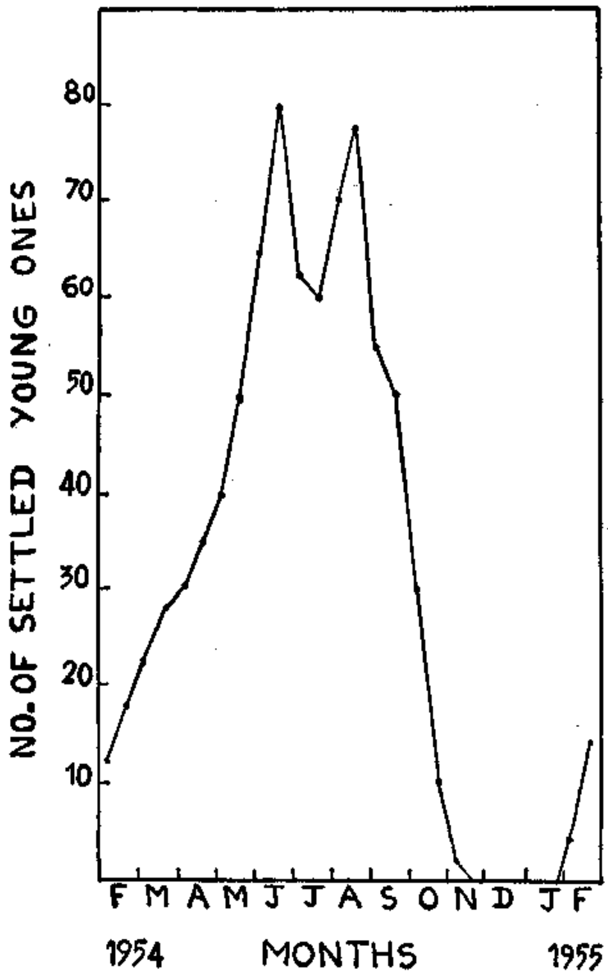

FIG. 4. The bi-weekly settlement of *Cynthia* sp.

Thirty individuals of an average length of 6 mm. were taken for the study and out of these 12 got themselves fixed to the bottom of the tank. However, the attachment was only feeble. It is seen from Table IX that the growth of the fixed ones was more rapid than the free ones. But their growth was not even as rapid as in the individuals of Canal, for, while the laboratory individuals added only 10 mm. in length in three months, those of a similar size at Canal recorded an addition of 16 mm. in three months. This poor growth under laboratory conditions indicates that, *Cynthia* sp., unlike the other two species studied, does not thrive well in the laboratory.

Sexual maturity and breeding

Well developed gonads with ripe eggs are seen in the individuals having a length of 11 to 14 mm. which may be attained in 20 to 25 days. Adults collected throughout the year have ripe eggs but there is no settlement of young ones during November to January.

The data on the settlement of young ones on experimental panels (Fig. 4) indicate that during November to January there is no settlement, though sexually mature animals have been observed. The settlement starting in February, gradually increases in number until it reaches a maximum during June-August. Then the rate of settlement rapidly falls and by November there is practically no settlement. It would thus appear that the breeding period of *Cynthia* sp. does not last the whole year and shows intense activity during June-August.

(d) ***Dasychone cingulata*** Grube

In the early stages after the larva settles the tube that is formed adheres to the substratum throughout its entire length, but later, it rises up at an angle to the surface. In this study, the entire vertical column of the tube is taken to represent the growth of the worm as is customarily done for the tube dwelling polychaetes.

Growth

From marked individuals.

TABLE X

A record of rate of growth in length in mm.

Age (days)	Boat Basin		New North Quay		Canal	
	Mean length	Increase in length	Mean length	Increase in length	Mean length	Increase in length
10	16	..	12	..	11	..
20	27	11	22	10	18	7
30	38	11	32	10	25	7
40	49	11	43	11	31	6
50	54	5	52	9	36	5
60	58	4	56	4	42	6
70	73	15	66	10	46	4
80	87	14	69	3	54	8
90	95	8	75	6	59	5
100	101	6	81	6	61	2
110	105	4	85	4	63	2
120	106	1	90	5	64	1
130	108	2	91	1	65	1
140	110	2	91	..	65	..
150	112	2	91	..	65	..
160	112	..	91	..	65	..

It is seen from Table X that maximum size is recorded at Basin, minimum at Canal and intermediate conditions prevail at Quay during a period of about five months. It may be also noticed that the mean increase in length is high during the first 40 days after attachment. Later, the growth declines. Then there is a sudden increase at the age of 70 days both at Basin and Quay.

In order to test whether the differential growth seen in the three stations is due to differences in the environment, observations were made by transplanting organisms from one station to another. It was seen that when planks having settlement of *D. cingulata* were removed from Basin and suspended in Canal, such individuals showed during the first month a greater increment than the original settlers of Canal but lesser than those at Basin. However, their growth rate fell during the subsequent period as a result of which both sets of individuals attained more or less a similar size in Canal. Similarly, when planks were removed from Quay and immersed in Basin, it was noticed that the Quay animals recorded a lesser growth than those of Basin during the first month. However, the loss was soon made up in the following months so much so at the end of four months both the sets reached almost a similar size.

Observations were also made on those settled in October as has been done on the other species. The sizes attained at the end of 30, 60, 90 and 120 days were, 32, 55, 93, and 106 mm. at Basin, 32, 56, 74 and 88 mm. at Quay and 20, 35, 56 and 62 mm. at Canal. A perusal of Table X shows that at the end of corresponding periods the lengths attained by the worms settled during other months were 38, 58, 95 and 106 mm. at Basin, 32, 56, 75 and 90 mm. at Quay and 25, 42, 59 and 64 mm. at Canal. A comparison of these records thus shows that, as in the other species studied, the total growth has not been much affected by the initial poor growth of first 30 days at Basin and Canal.

From random samples.

TABLE XI

A record of mean growth in mm. from random samples

Date of Collection	Boat Basin		Canal	
	No.	Length	No.	Length
15-11-53	69	10	45	5
14-12-53	73	45	40	30
11-1- 54	61	63	47	47
15-2- 54	59	102	40	64
22-3- 54	62	110	41	69
19-4- 54	57	118	43	72
21-6- 54	55	126	39	83
15-7- 54	49	131	40	88
16-8- 54	50	135	39	95
20-9- 54	43	140	32	98
18-10-54	39	143	30	99
15-11-54	36	147	31	99
20-12-54	40	148	30	100

Since this species does not settle in large numbers at Quay, observations on random samples from this station could not be maintained. Table XI shows that the maximum length recorded at Basin and Canal are 148 and 100 mm. respectively in 13 months. This shows a further increment of 36 and 35 mm. at the respective stations from those taken on marked individuals for five months. Thus, on an average, as much as 50% of their total growth of one year is attained in 70-75 days, 60% in 80-90 days, 70% in 100-120 days, 80% in 160-180 days and 90% in 240-260 days. It is further seen that the differences in the rate of growth at the two stations are only during the first five months after which, the growth increments at the two stations are more or less similar.

At different depth levels.

TABLE XII

A record of mean growth in mm. at different depths

Age	1′	3′	5′	7′	9′	12′
1 month	38	40	37	34	32	30
2 months	58	61	58	54	49	45
3 months	95	98	96	90	82	80
4 months	106	108	106	100	98	85

It is seen from Table XII that, as in the other species, rapid growth is observed in the panels up to 5′ level. At 7′ and 9′, the rate of growth is slow and at the level of 12′, growth is comparatively poor.

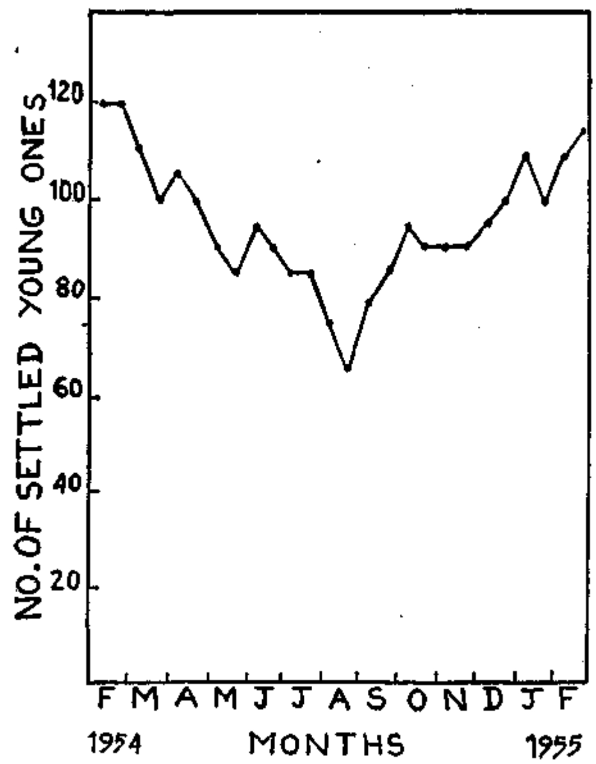

FIG. 5. The bi-weekly settlement of *Dasychone cingulata*.

Sexual maturity and breeding

Examination of gonads in a number of worms showed that ripened sexual products were found in those measuring 23 to 27 mm. in length, *i.e.* tube length of 45 to 55 mm. which may be attained under normal conditions in 40-50 days. Throughout the year the individuals of this size and age were sexually mature.

The settlement of larvae is continuous throughout the year with a maximum during January to February when as many as 110-120 individuals have settled on 160 sq. in. area during two-week periods (Fig. 5). After this maximum, there is a slow decline in the following months but after August, the settlement shows a progressive increase culminating in a peak during January-February. Thus, it appears that *D. cingulata* is a prolific breeder throughout the year with an intense breeding activity during December to March. Unlike the other species studied, the breeding of this organism does not show marked variations during different months of the year and there is only one peak of intense activity.

Discussion

Growth

Paul (*op. cit.*) has noticed a very rapid rate of growth in the sedentary organisms of the Madras harbour. In the present study also a similar feature is recorded since, from the observations for one year on random samples, it is seen that all the forms studied attain almost their maximum size within the first six months and then the growth slows down.

Factors like salinity, depth, food supply and spawning activity appear to influence the growth of these four sedentary organisms as recorded in other regions. That much lowering in salinity affects the growth of sedentary organisms has been shown by Hopkins (1936), Erlanson (1936), Coe (1948), Rao (1951), Abraham (1953) and Rao and Nayar (1956). During the present study, it is noticed that the individuals, which settle in October, show a decrease in growth at Basin and Canal during the first month of growth. During this month, the salinity values go down to 20.5‰ from 32.0‰ in Basin due to influx of fresh and impure water into this area. As the other environmental factors do not undergo appreciable changes during this month (Antony Raja, *op. cit.*), it is presumed that the marked lowering in salinity retards the growth of the individuals of Basin and Canal. This presumption is further supported when the uninterrupted growth records taken at Quay, where the salinity values are not affected during October, are compared. However, it is also noticed that perhaps only very young individuals are susceptible to the changes in salinity because it is seen that, the retardation of growth is observed only during the first month after settlement.

Regarding the influence of depth, Newcombe (1935), Warren (1936), Coe and Fox (1942) and Barnes and Powell (1953) have reported that growth is more rapid in those animals which are continuously or almost continuously submerged than those which are exposed. Loosanoff and Engle (1943) have observed that *Mytilus edulis* submerged completely at the upper levels have grown most rapidly, those at the bottom slower and those completely exposed have shown no increment at all, which has been later supported by Fuller (1946). The results reported in the preceding pages on the effect of depth on the growth of *M. striatulus* are in conformity with the above observations on mussels, for, this species also grows well between 1 and 5′ below low water, less so at bottom levels and similarly in the region exposed for some hours during the day. The results on *Cynthia* sp. and *D. cingulata* also are similar with the exception that no study was possible on the exposed forms.

It is well known that constant food supply is of prime importance for the growth of organisms. A close correlation between availability of organic detritus derived from the dead cells of marine micro-organisms and growth is suggested by Coe (1948). The possibility of higher organic detritus at Basin has already been shown (Antony Raja, *op. cit.*). The Quay is also an area rich in food supply, for there is a constant flow of fresh sea water from the open sea. At these two stations growth has been found to be rapid whereas in Canal region where there is less of wave action and inadequate supply of fresh sea water and consequently limited suspended particles of food, slower rate of growth and smaller sizes have been observed. Such a feature has also been reported by Paul (*op. cit.*) at Timber pond of the Madras harbour which is just adjacent to Canal. That lack of organic detritus can impede the growth rate is also supported by the results obtained from the laboratory experiments where no attempts were made for food supply except to change water twice daily.

Apart from these, biological factors like spawning influence the growth rate of sessile organisms. While Coe (1947), Quayle (1952) and Abraham (*op. cit.*) have observed decreased growth during spawning, it has been shown by Coe (1945), Rao (1951), Nayar (1955) and Rao and Nayar (*op. cit.*) that growth is not interrupted during spawning. Coe and Fox (1942) and Fox and Coe (1943) have observed in *Mytilus californianus* a fall in growth rate during spawning coupled with a temporary increase after spawning. Such a feature is seen in *D. cingulata* during the present study, for in this species, there is retardation of growth at the time of spawning, during 40-60 days, when they become sexually mature and during post-spawning period, at the age of 70-90 days, there is a temporary faster rate of growth (Table X). In *M. striatulus* and *Cynthia* sp., however, a reverse of the above function appears to occur, for, their growth rate does not appear to be arrested or retarded at the age of their sexual maturity and spawning but a decreased growth is noticed after the age at which they would have spawned. In *M. striatulus* this decrease is seen after 40 days of growth and in *Cynthia* sp., after 30 days, that is, after they have attained full maturity (Tables I & VI). It has been also observed in the laboratory that individuals spawn immediately after maturation, thereby showing that the spawning may not be delayed and hence, it can be stated that in these two species the post-spawning period is characterised by slower growth. Since *Bowerbankia* sp. attains sexual maturity in a week after settlement, it may be said that its rapid rate of growth coincides with its attainment of sexual maturity.

Sexual maturity and breeding

It is generally agreed that as a result of high metabolic activities in the tropics, the organisms attain maturity very early (Aiyar, 1933 ; Paul, *op. cit.*). The results obtained during this investigation confirm the above view, for, *M. striatulus* and *Cynthia* sp. reach sexual maturity in 30 days, *D. cingulata* in 40-50 days and *Bowerbankia* sp. in as early as one week.

Stephenson (1934) has observed that based on the breeding periodicity, the animals can be grouped under four types. In the light of findings recorded in the preceding pages on the breeding of the four sedentary organisms, *M. striatulus* may be put under the second type in having ' a continuous breeding throughout the year but more active in one part of the year than during the remainder ' with a slight modification that the intense activity is twice in this species instead of once. Paul has also classified another mussel *Mytilus viridis* under the same type. *Bowerbankia* sp. also falls in the same category by virtue of its breeding periodicity. On the other hand, *Cynthia* sp. can be put along with those having ' a single breeding period not lasting the whole year ' (Stephenson, *loc. cit.*) and in this connection mention may be made of Paul's findings on another ascidian, *Polycarpa* sp. whose sexual activity also does not last the whole year. Unlike these three species, the breeding of *D. cingulata* although showing a peak period of intense activity does not present marked variations during different months of the year. Another polychaete, *Hydroides nervegica*, also has been reported to show similar breeding activity all through the year (Paul, *op. cit.*; Daniel, *op. cit.*).

SUMMARY

The rate of growth of four sedentary organisms, namely, *Modiolus striatulus*, *Bowerbankia* sp., *Cynthia* sp. and *Dasychone cingulata* has been sudied. For such a study, data have been collected from (i) marked individuals, (ii) random samples of natural populations and (iii) individuals reared under the laboratory conditions. The growth studies in the field have been carried out at three stations of the Madras harbour, namely, New North Quay, Boat Basin and Canal. It is seen that growth is markedly poor at Canal and at the other two stations it is more or less similar. Under laboratory conditions, the rate of growth shows a similarity to that recorded at Canal.

All the forms studied attain almost their maximum size within six months. Rapid rate of growth and earlier attainment of sexual maturity are features noticed in the organisms studied. Influence of factors like salinity, depth, food supply and spawning activity on growth has been discussed in the light of previous work on the subject.

The breeding periodicities of these animals have been determined from the bi-weekly settlement of the young ones. While *M. striatulus*, *Bowerbankia* sp. and *Dasychone cingulata* breed throughout the year with peak period(s) of intensity during certain part(s) of the year, in *Cynthia* sp., breeding does not last the whole year.

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