STUDIES ON THE GROWTH OF THE WEDGE CLAM, *DONAX* (*LATONA*) *CUNEATUS* LINNÆUS

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Introduction

Of the several species of wedge clams of the family *Donacidæ* that occur on the east and west coasts of India in the surf-beaten sands, *Donax scortum* to some and *Donax cuneatus* to a very large extent are valued as food by many people. In the Palk Bay, all along the beach from Pillaimadam shore (Long. 79° 5′ and Lat. 9° 17′) to Attankarai (Long. 79° 0′ and Lat. 9° 21′), a distance of about seven miles, the receding tides reveal *Donax cuneatus* in abundance. It forms the food of a large number of fishermen along the coast when the sea is rough and the general fishery conditions poor. It is usually fished only during such off-seasons and is not sold in the open market. The clam meat is cooked whole or made into a paste and treated with condiments in the preparation of curries. Dead shells of these clams, washed ashore, are collected by the womenfolk for preparing lime. However, at present there is no regular fishery of these clams for food or any organised lime burning industry, with the result that this valuable resource is wasted without being much utilized. The present investigation was taken up with a view to exploring the possibilities of exploitation of this resource of food without any undue damage to the beds.

In countries abroad, where shell-fish are used as food more commonly than in India, a considerable amount of work on the growth of these lamellibranchs has been done. Weymouth (1923) on *Tivela stultorum*, McMillin (1924), Weymouth *et al.* (1925) on *Siliqua patula*, Kellog (1903) on *Venus mercenaria*, Crozier (1914) on *Dosinia discus*, Mossop (1922) on *Mytilus edulis* and Newcombe (1935 and 1936) on *Mya arenaria* have furnished very valuable information on the growth of the American species of shell-fish. Similar work has been done in Britain by Orton (1926) on *Cardium edule*, Stephen (1928, 1929 and 1932) on *Tellina tennuis*, Davis (1923) on *Spisula subtruncata*, Quayle (1952) on *Venerupis pullastra* and Ford (1925) on a few other sublittoral species. Information available on the growth of bivalve

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molluscs of economic importance in the Indian waters is scanty. The only published accounts are by Winckworth (1931) on *Paphia undulata*, Paul (1942) on *Ostrea madrasensis* and *Mytilus viridis*, Rao (1951) on *Katelysia opima*, Abraham (1953) on *Meretrix casta* and Gokhale, *et al*. (1954) on *Pinctada pinctada*. Growth studies by Herdman (1903) and Malpas (1933) on the Pearl oyster, *Pinctada vulgaris*, and Pearson (1905) on the window pane oyster of Ceylon coast in the Gulf of Mannar have furnished information on some aspects of the growth of these forms in the waters adjacent to the Indian shores.

MATERIAL AND METHODS OF STUDY

Random samples of wedge clams, *Donax cuneatus*, were obtained regularly once in ten days for a period of seventeen months, from February 1952 to June 1953, from the sandy shore of Palk Bay near Akkadavalasai, at a distance of about two miles north of Uchippuli Railway Station on the Southern Railway. The clams occur in the surf-line along the shore and their presence is revealed by a pair of openings for each individual on the wet sands, indicating the positions of the siphons lying below. The receding waves very often dislodge the clams out of their burrows. They then immediately burrow into the wet sand with the help of the foot and lie secure therein, until another wave washes them out. Every time a collection was made, a wooden frame of one foot square was fixed on the shore and all the sand with the clams from the enclosed space to a depth of about 9″—beyond which the clams seldom burrow—was sieved so as to allow the sand to pass through the meshes, leaving the clams in the sieve. Collections, thus made, were used in determining the density of population. The meshes of the sieve were nearly of 1 mm. squares. It was therefore possible to obtain even the youngest clams just settled. After the breeding season, when the young clams were settling, a different sieve with a finer mesh was also used so as to obtain even the smallest clams. Growth rate was determined by the size-frequency method. The greatest antero-posterior measurement was taken as the length, the distance from the hinge to the ventral margin of the valves as breadth and the maximum distance between the two valves as width. Length was taken as the standard of measure for determining the age. The clams were measured with sliding calipers correct to one-tenth of a mm. and were grouped in sizes with class intervals of 1 mm. The percentages of different size groups of the total number of clams measured for each month were represented by graphs. The shifting of the mode values in the graphs for different months indicated the average growth rate of the different year-classes from month to month. The salinity and temperature of the waters of the Palk Bay near Akkadavalasai were regularly recorded to ascertain their effect, if any, on the growth and breeding of the clams. The gonadic condition of about 100 clams of different size groups in each sample of nearly 1,000 was examined with a view to determining the age and size at sexual maturity and the period of spawning. The very small clams, where the nature of the gonadic condition could not be determined in fresh preparations, were fixed in Bouin's fluid and serial sections of them were prepared and stained for observations. In a large number of clams breadth, thickness and weight were also measured to find out the length-breadth, length-thickness and length-weight relationships.

Period of Life and Growth of Year-Classes

Spawning starts by about January and lasts till April, as revealed by periodical examination of the condition of the gonads in adult clams. The young clams, after settling on the beds, grow to the adult size in about nine months. Mortality is very great in the months October-November and June-July. A large percentage of clams seems to die during the second year of their lives.

The length frequencies of the clams observed during February 1952 to June 1953, for a period of seventeen months, are represented in the frequency Table I and by graphs in Fig. 1. The three collections of samples made at intervals of ten days are combined in each month, where there is a uniformity of distribution from sample to sample. However, in November 1952 the three samples are treated separately as they vary to some extent and show definite movement of the peak values of the young clams merging with the adult ones.

As seen in Fig. 1, in February, March and April 1952 the samples reveal only adult clams with a single mode value at 16 mm. The majority of the adult clams are between 14 mm. and 18 mm. range. These appear to comprise the second year-class. Spawning probabiy commenced in January 1952, as supported by observations made subsequently in the year 1953, but young ones are not represented in the collections from February to April 1952, owing probably to defective sampling.

In May 1952 the peak value of the adult clams is at 16 mm., as in the previous months. Young clams comprising the new year-class, ranging from 1 to 3 mm. in length, are obtained for the first time in this month. It has been observed that the very young clams do not settle exactly at the surf-line, where the adults occur, but a little farther away from it at about the low-water-mark.

TABLE I

Showing the Number and Percentage Frequencies of Clams of Different Size Groups for Various Months

Size groups mm.	February 1952		March 1952		April 1952		May 1952	
	No.	%	No.	%	No.	%	No.	%
1– 2	..	..	..	..	..		16	·83
2– 3	..	..	..	..	..	..	88	4·60
3– 4	..	..	..	..	..	..	12	·62
4– 5	..	..	..	..	..	..	..	..
5– 6	..	..	..	..	..	..	..	..
6– 7	..	..	..	..	..	..	..	..
7– 8	..	..	..	..	..	..	..	..
8– 9	..	..	..	..	1	0·05	..	..
9–10	..	..	..	..	..	..	1	0·05
10–11	..	..	1	0·05	1	0·05	1	0·05
11–12	4	0·17	..	..	..	..	..	..
12–13	4	0·17	4	0·21	1	0·05	4	0·20
13–14	29	1·25	29	1·55	25	1·30	6	0·31
14–15	187	8·08	159	8·53	144	7·53	57	2·97
15–16	495	21·39	415	22·26	446	23·32	259	13·53
16–17	713	30·81	618	33·15	731	38·23	606	31·67
17–18	522	22·55	382	20·49	440	23·01	465	24·30
18–19	252	10·89	161	8·63	104	5·43	276	14·42
19–20	74	3·19	76	4·07	16	0·83	94	4·91
20–21	20	0·86	16	0·85	3	6·15	27	1·41
21–22	12	0·51	3	0·16	..	..	1	0·05
22–23	2	0·08	..	..	..	..	..	..
23–24	..	..	..	..	..	..	..	..
24–25	..	..	..	..	..	..	..	..
Total ..	2,314		1,864		1,912		1,913	
Min. ..		11·5		10·2		8·7		1·4
Max. ..		22·4		22·8		20·6		20·3
Mean ..		16·66		16·59		16·43		16·04
S. D. ..		1·38		1·53		1·23		4·23
S. E. ..		0·03		0·04		0·03		0·09

TABLE I—(*Continued*)

Size groups mm.	June 1952		July 1952		August 1952		September 1952	
	No.	%	No.	%	No.	%	No.	%
1– 2	452	10·31	9	·20	..	..	..	..
2– 3	1,440	32·86	500	11·16	56	1·15	1	0·02
3– 4	341	7·78	868	19·37	707	14·59	42	1·02
4– 5	106	2·41	486	10·84	944	19·47	369	8·97
5– 6	33	0·75	176	3·92	492	10·15	459	11·15
6– 7	18	0·41	69	1·54	273	5·63	433	10·52
7– 8	3	0·06	31	0·69	121	2·49	260	6·32
8– 9	3	0·06	11	0·24	65	1·34	216	5·25
9–10	3	0·06	6	0·13	46	0·95	161	3·91
10–11	7	0·15	3	0·06	15	0·31	99	2·41
11–12	2	0·04	1	0·02	9	0·18	70	1·70
12–13	2	0·04	4	0·08	5	1·10	28	0·68
13–14	5	0·11	6	0·13	4	0·08	11	0·26
14–15	37	0·84	41	0·91	27	0·55	24	0·58
15–16	193	4·40	256	5·71	197	4·06	166	4·03
16–17	567	12·94	807	18·01	712	14·69	684	16·63
17–18	585	13·35	828	18·48	834	17·21	784	19·06
18–19	385	8·78	330	7·36	298	6·14	276	6·71
19–20	168	3·83	43	0·95	39	0·80	29	0·70
20–21	28	0·64	4	0·08	1	0·02	1	0·02
21–22	3	0·06	..	..	1	0·02	..	..
22–23	..	..	1	0·02	..	..	..	..
23–24	..	..	..	..	..	..	..	..
24–25	..	..	..	..	..	..	..	..
Total ..	4,381		4,480		4,846		4,113	
Min. ..		1·6		1·6		2·4		2·8
Max. ..		20·9		22·8		21·7		20·7
Mean ..		9·34		10·68		10·26		11·77
S. D. ..		7·33		6·69		6·17		5·38
S. E. ..		0·11		0·09		0·09		0·08

TABLE I—(*Continued*)

Size groups mm.	October 1952		10th Nov. 1952		21st Nov. 1952		29th Nov. 1952	
	No.	%	No.	%	No.	%	No.	%
1– 2	..	..	..	..	..	..	..	..
2– 3	..	..	..	..	..	..	..	..
3– 4	..	..	..	..	..	..	..	..
4– 5	50	1·39	..	..	..	..	..	..
5– 6	190	5·30	1	0·12	..	..	..	..
6– 7	277	7·72	10	1·21	..	..	..	..
7– 8	336	9·37	27	3·26	..	..	..	..
8– 9	260	7·25	30	3·26	6	0·91	1	0·11
9–10	205	5·71	44	5·32	15	2·28	3	0·35
10–11	147	4·10	34	4·11	20	3·04	7	0·82
11–12	105	2·92	32	3·87	20	3·04	28	3·30
12–13	79	2·20	22	2·66	29	4·41	38	4·48
13–14	33	0·92	13	1·57	30	4·56	41	4·83
14–15	26	0·72	20	2·42	24	3·65	40	4·71
15–16	84	2·32	21	2·54	20	3·04	34	4·01
16–17	507	14·14	144	13·80	62	9·43	60	7·07
17–18	841	23·46	244	29·53	147	22·37	222	26·17
18–19	387	10·79	180	21·79	216	32·87	280	33·01
19–20	53	1·47	33	3·99	63	9·58	85	10·02
20–21	3	0·08	1	0·12	5	0·76	9	1·06
21–22	1	0·02	..	..	..	..	..	..
22–23	..	..	..	..	..	..	..	..
23–24	..	..	..	..	..	..	..	..
24–25	..	..	..	..	..	..	..	..
Total ..	3,584		856		657		848	
Min. ..		4·8		5·3		8·3		8·9
Max. ..		21·3		20·5		20·9		20·5
Mean ..		13·10		15·63		16·72		17·06
S. D. ..		4·81		3·5		2·7		2·2
S. E. ..		0·08		0·12		0·11		0·08

TABLE I—(*Continued*)

Size groups mm.	December 1952		January 1953		February 1953		March 1953	
	No.	%	No.	%	No.	%	No.	%
1– 2	..	..	3	·17	6	·26	..	..
2– 3	..	..	6	·34	257	11·44	3	·17
3– 4	..	..	..	..	141	6·27	6	·34
4– 5	..	..	..	..	41	1·82	13	·74
5– 6	..	..	1	·05	21	·93	13	·74
6– 7	..	..	..	..	18	·80	11	·62
7– 8	..	..	..	..	3	·13	7	·39
8– 9	..	..	..	..	4	·17	14	·79
9–10	..	..	..	..	7	·31	10	·56
10–11	2	·10	1	·05	4	·17	13	·74
11–12	3	·16	..	..	2	·08	4	·22
12–13	8	·43	..	..	..	..	8	·45
13–14	18	·98	1	·05	..	..	7	·39
14–15	30	1·64	..	..	1	·04	3	·17
15–16	66	3·62	21	1·19	12	·53	3	·17
16–17	102	5·59	51	2·89	45	2·00	37	2·10
17–18	284	15·57	184	10·45	167	7·43	154	8·75
18–19	633	34·70	605	34·37	562	25·02	570	32·38
19–20	557	30·53	633	35·96	680	30·27	603	34·26
20–21	110	6·03	233	13·23	247	10·99	238	13·52
21–22	10	·54	19	1·07	28	1·24	31	1·76
22–23	1	·05	2	·10	..	..	10	·56
23–24	..	..	..	..	..	..	2	·10
24–25	..	..	..	..	..	..	..	..
Total ..	1,824		1,760		2,246		1,760	
Min. ..		10·6		1·6		1·9		2·4
Max. ..		22·4		22·9		21·5		23·9
Mean. ..		18·41		18·87		15·55		18·39
S. D. ..		1·54		1·55		6·60		2·99
S. E. ..		0·03		0·03		0·14		0·07

TABLE I—(*Continued*)

Size groups mm.	April 1953		May 1953		June 1953	
	No.	%	No.	%	No.	%
1– 2	..	..	126	3·26	5	·11
2– 3	10	·54	1,099	28·43	108	2·47
3– 4	17	·91	737	19·06	615	14·09
4– 5	28	1·51	559	14·46	722	16·54
5– 6	37	1·99	221	5·71	673	15·42
6– 7	49	2·63	73	1·88	608	13·93
7– 8	71	3·82	52	1·34	488	11·18
8– 9	31	1·67	42	1·08	279	6·39
9–10	27	1·45	42	1·08	175	4·02
10–11	14	·75	46	1·19	101	2·31
11–12	14	·75	25	·64	69	1·58
12–13	12	·65	22	·56	77	1·76
13–14	24	1·29	15	·38	73	1·67
14–15	24	1·29	11	·28	66	1·51
15–16	17	·91	10	·25	37	·84
16–17	42	2·26	20	·51	32	·73
17–18	159	8·55	32	·82	18	·41
18–19	428	23·01	146	3·77	47	1·07
19–20	550	29·57	312	8·07	81	1·85
20–21	259	13·92	225	5·82	67	1·53
21–22	44	2·37	45	1·16	20	·45
22–23	3	·16	5	·12	2	·05
23–24	..	..	..	..	..	..
24–25	..	..	..	..	..	..
Total ..	1,860		3,865		4,363	
Min. ..		2·8		1·7		1·8
Max. ..		22·8		22·9		22·8
Mean. ..		17·00		7·40		7·22
S. D. ..		4·15		6·58		4·08
S. E. ..		0·09		0·15		0·06

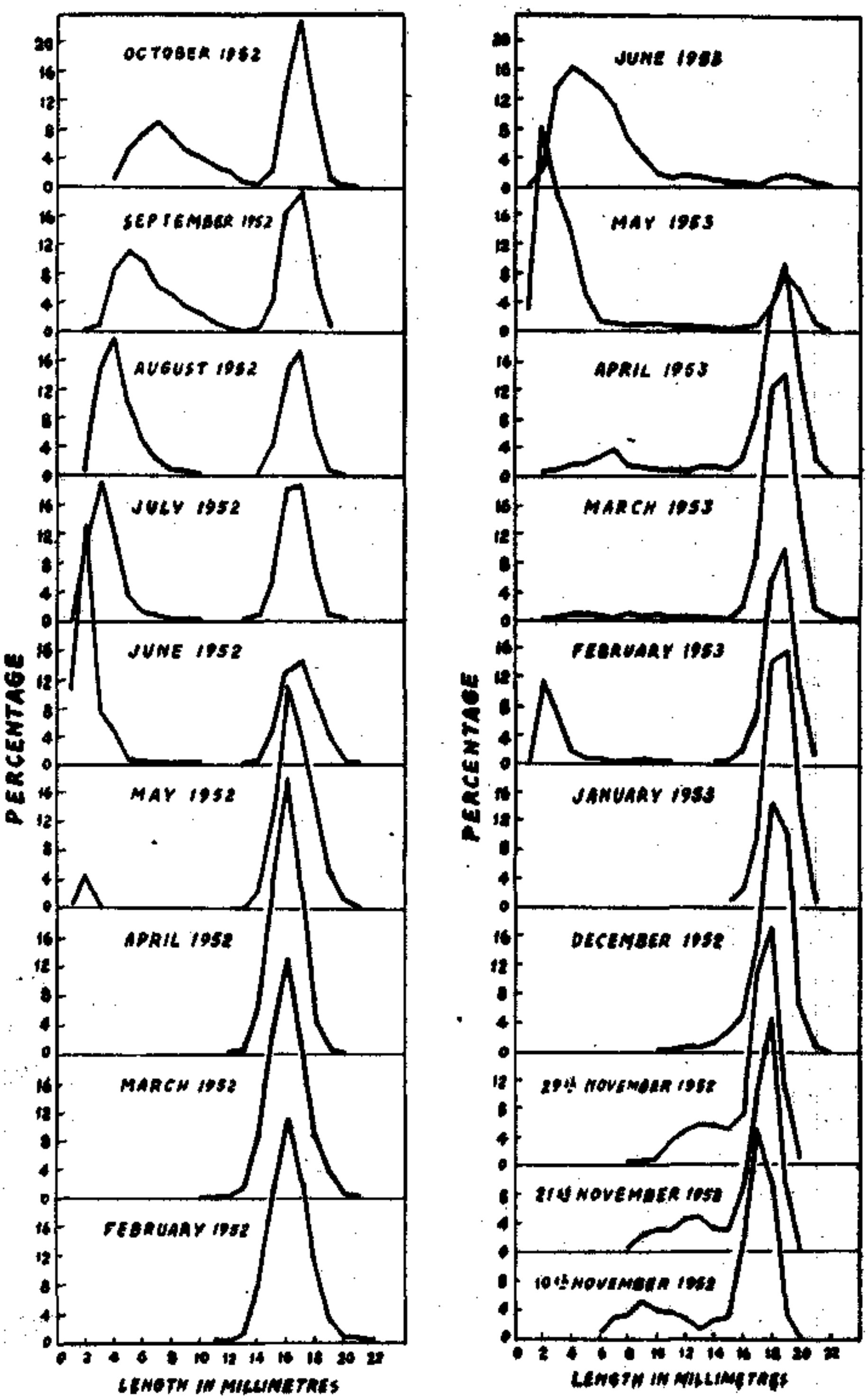
OCTOBER 1952
SEPTEMBER 1952
AUGUST 1952
JULY 1952
JUNE 1952
MAY 1952
APRIL 1952
MARCH 1952
FEBRUARY 1952
PERCENTAGE
LENGTH IN MILLIMETRES
JUNE 1953
MAY 1953
APRIL 1953
MARCH 1953
FEBRUARY 1953
JANUARY 1953
DECEMBER 1952
29th NOVEMBER 1952
21st NOVEMBER 1952
10th NOVEMBER 1952
PERCENTAGE
LENGTH IN MILLIMETRES

FIG. 1

In June 1952 the mode value of the adult clams has shifted to 17 mm. from 16 mm., as observed in the previous months.† This remains steady in the subsequent months till October 1952. In all the months from June to October there is the occurrence of large numbers of young clams. They show a steady increase in their rate of growth as represented by the shifting of the peak values from 2 mm. to 3 mm., 4 mm., 5 mm. and 7 mm. in successive months.

The sample collected on 10th November 1952, as indicated in graph (Fig. 1), shows the mode value of the adult clams at 17 mm. as in the previous months. Clams of the first year-class show a mode value of 9 mm., but a fair number of them have already grown to a larger size, as indicated by the gradual merging of them with those of the second year-class.

In the graph for the collection made on 21st November 1952 clams of the second year-class reveal a modal value of 18 mm., with an increase of an average growth of 1 mm. as compared with that observed in the previous collection. Clams of the first year-class are represented by a small mode at 10 mm. and a larger one at 13 mm.

In the collection made on 29th November 1952 the mode value of the second year-class remains at 18 mm. whereas that of the first year-class is at 13 mm. In this and the previous collections there are no clams below 8 mm. in length. Graphs for the collections made on 10th, 21st and 29th November 1952 show a gradual merging of the individuals of the first year-class with those of the second year-class.

In the graphs for December 1952 no young clams below 10 mm. length are indicated. Majority of the clams fall between 16 mm. and 20 mm. The absence of a definite mode for the first year-class indicates a thorough merging of the first year-class with the second year-class. The increased percentages in the size groups for larger clams for this month, as compared with those in the previous months shown in the frequency table, also indicate merging of the new year-class of 1952 with the older clams.

In January 1953 the graph shows the shifting of the mode value of the adult clams from 18 mm. to 19 mm. That a fresh year-class of 1953 has commenced entering the populations is revealed by the occurrence of very young individuals of 1 to 2 mm. in length. Allowing a margin of about 2 to 3 weeks for embryonic and larval life and a brief period for setting and growth to 1 or 2 mm. in length, it may be assumed that spawning had started by about the beginning of January 1953.

† In June 1955 the author collected a number of samples which confirmed the observations recorded for the same month in 1952 and 1953.

In the collections of February, March and April 1953 adult clams show a steady mode value of 19 mm. The younger clams of 1953 year-class show a prominent mode at 2 mm. in February 1953, which shifts to 4 mm. and 7 mm. in the subsequent months.

In the month of May 1953 it is found that the larger clams are not obtained in such abundance as in the previous months, and in June 1953 their numbers are found to dwindle still further. Similar mortality of the adult clams has occurred in the month of October 1952 also. These instances of adult mortality are evident in Table VII which shows the changes in the density of population. Fig. 1 does not show a corresponding fall in the percentage of adults because, for studies on rate of growth and age composition, clams from a larger area had to be collected during these months irrespective of the changes in density of population. About the same time it is observed that a number of dead and dying ones are cast ashore. Young clams of the 1953 year-class begin to enter the populations in large numbers which is due to peak spawning by about April. The late arrival of this year-class has a mode value of 2 mm. in May and 4 mm. in June. Between the populations of the late arrivals of the new year-class with a mode value of 4 mm. and those of the second year-class with a mode value of 19 mm. there are members of the early arrivals of the new year-class.

Length-Weight, Length-Breadth and Length-Thickness Relationships

During March, April and May 1952, when clams of different sizes ranging from 1 mm. to 22 mm. in length occurred, the length-weight relationship of 825 clams was determined. For this purpose clams were fixed in 5% Formaldehyde (B.D.H.) in sea water, in which they were allowed to remain for ten days, then taken out, wiped dry on a blotting sheet, measured and weighed. As it was found difficult to weigh very small clams individually, lots of ten to fifteen, belonging to the same size groups, were weighed together and the average determined. The salinity of the sea water used in the preservative was the same in all the samples thus treated. The preservative was used to regulate the amount of fluid content of the clams, which varied from individual to individual, depending upon the quantity of water present in the mantle cavity when taking the weights. Table II shows the average observed weights for size-groups of different lengths. From the observed weights the calculated weights have been determined by the application of the formula $W = AL^{\alpha}$. It was found that $W = \cdot 00045\ L^{2 \cdot 8079}$ or $\text{Log}\ W = -\cdot 05165 + 2\cdot 8079\ \text{Log}\ L$, where W and L stand for weight and length.

TABLE II

Showing the Average Observed and Calculated Weights of the Clams

Size groups mm.	Number of individuals				Average weight mm.	Calculated weight mm.
	Un-sexed	Male	Female	Total		
1– 2	27	..	..	27	·0018	·0010
2– 3	314	..	..	314	·0029	·0040
3– 4	88	..	..	88	·0080	·0103
4– 5	43	..	..	43	·0150	·0208
5– 6	5	..	..	5	·0350	·0365
6– 7	10	..	..	10	·0530	·0583
7– 8	9	..	..	9	·0780	·0872
8– 9	13	..	..	13	·1250	·1240
9–10	47	..	...	47	·1820	·1693
10–11	32	..	..	32	·2400	·2244
11–12	21	..	..	21	·3170	·2896
12–13	24	..	..	24	·3820	·3660
13–14	13	..	..	13	·4530	·4542
14–15	..	7	5	12	·8800	·5554
15–16	..	21	12	33	·6730	·6694
16–17	..	38	37	75	·8130	·7982
17–18	..	48	32	80	·9710	·9412
18–19	..	36	21	57	1·1700	1·1010
19–20	..	20	13	33	1·3100	1·2760
20–21	..	7	4	11	1·4700	1·4690
21–22	..	2	..	2	1·7400	1·6780

It may be seen from the figure that the calculated weights for different size groups agree very closely with the observed weights.

Length-breadth and length-thickness relationships of 1,575 clams of different size groups were also determined (Table III and Fig. 3). The same formula as in determining the length-weight relationship was used to determine the length-breadth and length-thickness relationships also. In the case of the former it was found that $\text{Log B} = -\cdot0715 + \cdot920 \text{ Log L}$ and in the latter $\text{Log T} = -\cdot4670 + 1\cdot0375 \text{ Log L}$, where B and T denote breadth and thickness respectively. From Fig. 3 it is clear that the calculated measurements give an excellent fit to the actual observed measurements of breadth and thickness.

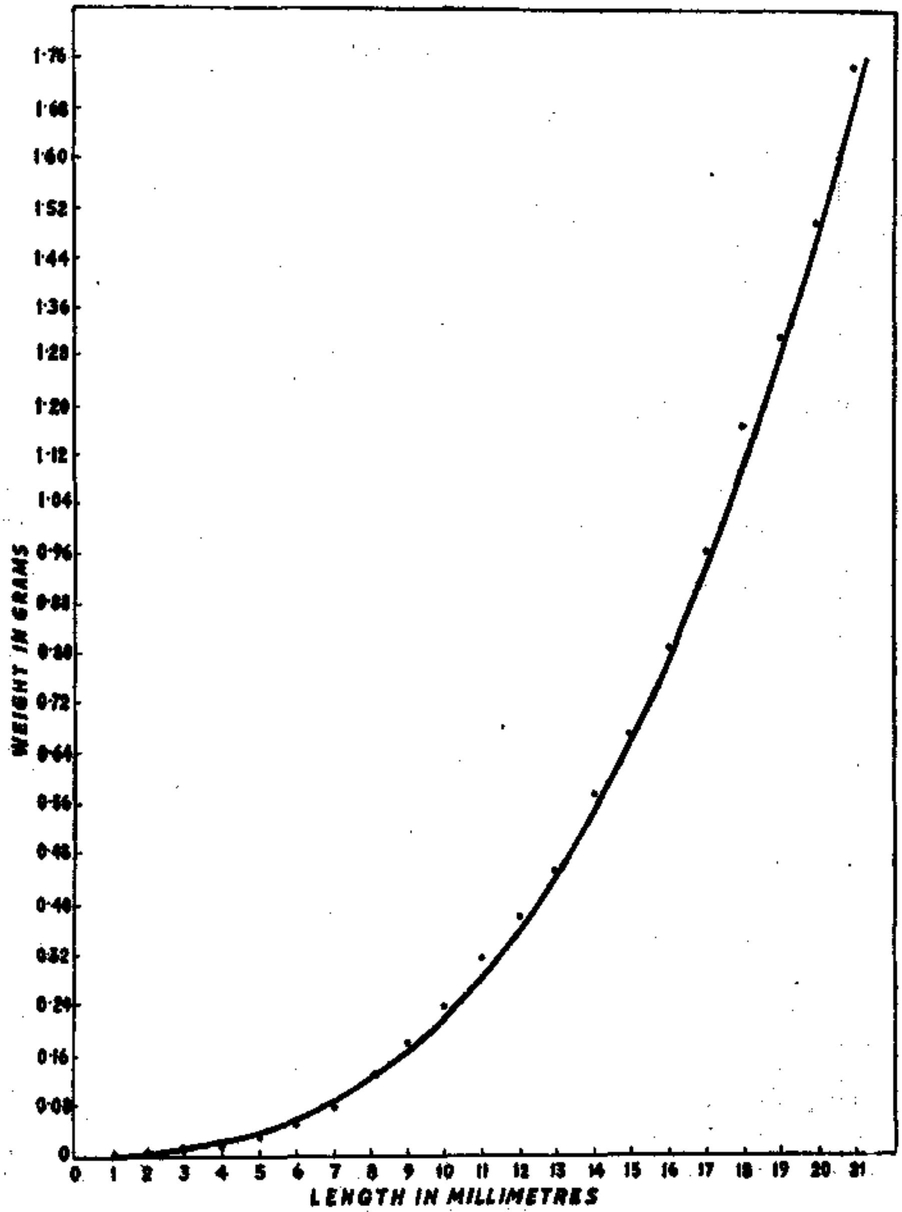

FIG. 2

As shown in Table IV breadth varies proportionately to the length in all the size groups, thereby indicating the general form is more or less the same throughout its life from the period of setting. Quayle (1952) in *Venerupis pullastra* has, however, found that height tends to approximate

TABLE III

Showing the Observed and Calculated Values of Breadth and Thickness of the Clams

Size group	Average length mm.	Sample size mm.	Average breadth mm.	Calculated breadth mm.	Average thickness mm.	Calculated thickness mm.
5– 6	5·61	11	4·15	4·19	2·01	2·04
6– 7	6·48	12	4·67	4·79	2·38	2·36
7– 8	7·51	14	5·54	5·49	2·77	2·75
8– 9	8·28	24	6·08	6·00	3·00	3·05
9–10	9·42	10	6·89	6·77	3·36	3·48
10–11	10·36	16	7·44	7·39	3·93	3·84
11–12	11·54	8	8·23	8·17	4·30	4·29
12–13	12·60	10	8·96	8·86	4·74	4·70
13–14	13·65	19	9·66	9·54	5·33	5·11
14–15	14·56	67	10·00	10·14	5·58	5·47
15–16	15·49	224	10·61	10·73	5·89	5·83
16–17	16·28	305	11·18	11·24	6·18	6·14
17–18	17·42	289	11·82	11·96	6·58	6·58
18–19	18·11	385	12·38	12·40	6·89	6·85
19–20	19·32	140	12·92	13·17	7·15	7·33
20–21	20·23	16	13·76	13·74	7·57	7·69
21–22	21·30	22	14·53	14·41	8·06	8·10
22–23	22·30	3	15·20	15·04	8·37	8·50

to length in early part of its life, but at 2 mm. the ratio changes to that found in the adult. He considers that the rapid adaptation of the spherical to oblong is conducive for burrowing. Considering that *D. cuneatus* is a littoral form subject to the pounding action of the surf, the quick assumption of an elongate form adapted for rapid burrowing in the sands would appear essential even at the moment of setting.

AGE AND SIZE AT SEXUAL MATURITY AND PERIOD OF SPAWNING

To determine the size at sexual maturity young clams ranging in size from 3 mm. onwards were microscopically examined in serial sections. In clams below 11 mm. in length the sections revealed no indication of sex. Spermatocytes in fair numbers and sperms in small numbers in males and developing ova in the females were met with in a few clams between 12 mm. and 13 mm. in length. All individuals from 14 mm. in length revealed ripe

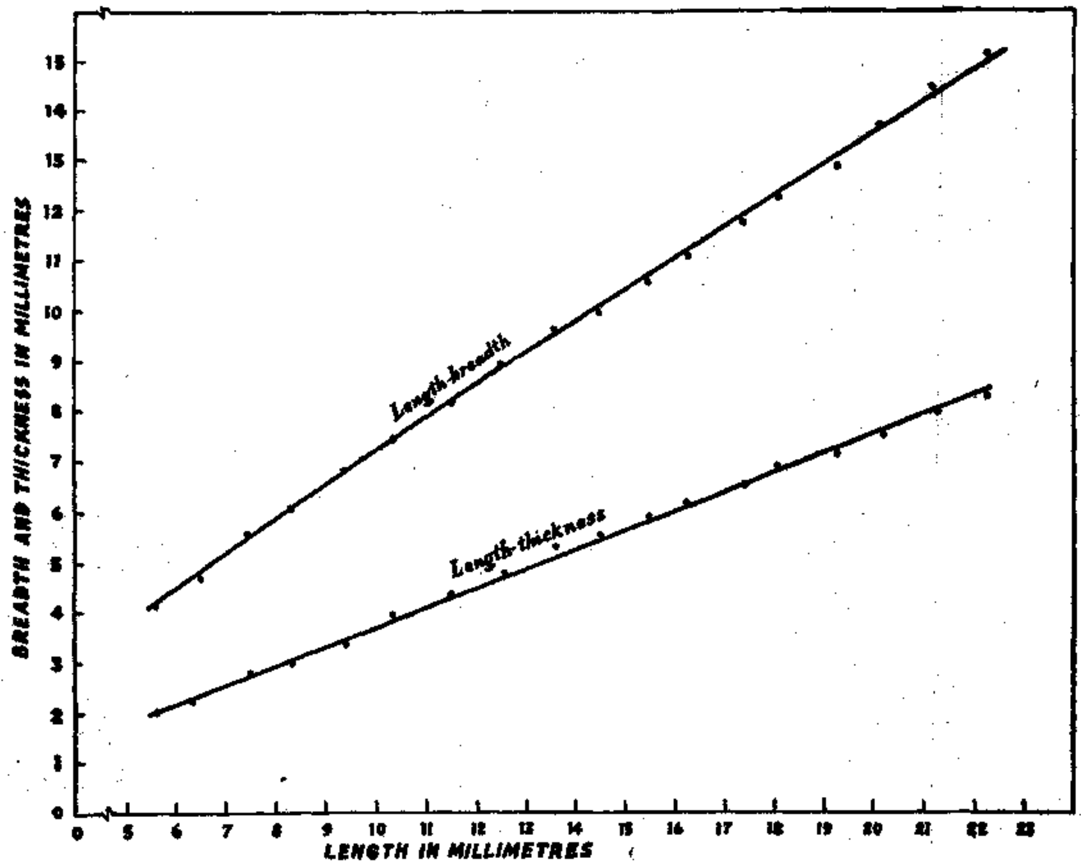

FIG. 3

TABLE IV

Showing the Height-Length Ratio of the Clam

Size groups mm.	Height / Length	Size groups mm.	Height / Length	Size groups mm.	Height / Length
1–2	0·70	9–10	0·73	16–17	0·68
2–3	0·70	10–11	0·71	17–18	0·67
3–4	0·70	11–12	0·71	18–19	0·68
4–5	0·71	12–13	0·71	19–20	0·66
5–6	0·74	13–14	0·70	20–21	0·68
6–7	0·72	14–15	0·68	21–22	0·68
7–8	0·73	15–16	0·68	22–23	0·68
8–9	0·73	..	..	..	..

sexual elements. As the individuals of the first year-class, which begin their life about January, grow up to an average length of 9 mm. to 13 mm. in November (Fig. 1), it is concluded that sexual maturity is attained when they are about 10 months old.

Examination of the gonads of adult clams revealed spent condition in a small percentage in February 1952, when this study was commenced. In March and April most of the clams had spent gonads. The largest number of spent ones were met with in May to July 1952. Clams examined during the period, September to November 1952, had their gonads in a state of recovery. In December 1952 the gonads were quite ripe in all the samples examined. In the year 1953 from January to July observations made on the gonadic condition conformed closely to what was observed in 1952.

As the sexual maturity is attained when they are about 10 months old in November, they spawn in January of the following year, when they are about one year old. As most clams perish after their second year they do not seem to spawn more than twice during their life-time.

From these observations the period of spawning appears to be very prolonged, extending from January to about April. The occurrence of a very large number of young ones in May for both the years 1952 and 1953 indicates that the majority of individuals spawn late in the breeding season by about April.

THE EFFECT OF TEMPERATURE AND SALINITY OF THE INSHORE WATERS ON BREEDING AND GROWTH OF THE CLAMS

Table V and Fig. 4 show the average values of temperature and salinity of the waters over the clam beds for different months during the period of observations from February 1952 to June 1953. The highest and the lowest temperatures recorded were 31·5° C. and 25·8° C. in March 1952 and December 1952 respectively. In general, very high temperatures, ranging from 29·6° C. to 31·5° C., prevail during March, April and May. From June to October the temperature remains almost steady fluctuating in a small range from 28·2° C. to 29·2° C. in November and was followed by a further drop to 25·8° C. in December. From January to March there was a steady increase from 26·2° C. to 29·2° C.

The highest and the lowest salinity values recorded during the period of observations were 35·91‰ in October and 24·39‰ in December respectively. In December and January the salinity values were very low, ranging from 24·39‰ to 25·51‰. Usually from February to October there is a steady rise.

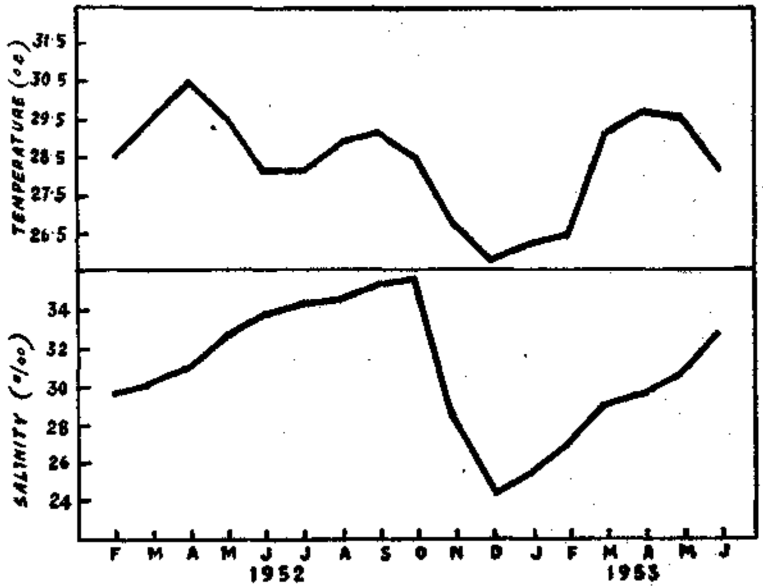

FIG. 4

TABLE V

Showing the Temperature and Salinity of the Inshore Waters of the Palk Bay for the Different Months

Month		Temperature °C.	Salinity ‰
1952			
February	..	28·5	29·88
March	..	31·5	30·40
April	..	30·5	31·20
May	..	29·6	32·90
June	..	28·2	33·96
July	..	28·2	34·58
August	..	28·9	34·89
September	..	29·2	35·55
October	..	28·6	35·91
November	..	26·8	28·47
December	..	25·8	24·39
1953			
January	..	26·2	25·51
February	..	26·3	27·10
March	..	29·2	29·10
April	..	29·7	29·57
May	..	29·6	30·71
June	..	28·2	32·80

As spawning starts in January it is preceded by a period when there is a sudden drop in salinity. Spawning is continued steadily after January, reaching a peak by about April. This period (January to April) is marked by a steady increase in temperature.

During September and October the salinity values were the highest and in the period closely following it, *i.e.*, October to November, there was a high mortality of the adult clams. Similar mortality of the clams was observed in the months of June and July also, which followed the period in which the highest temperatures were recorded, *i.e.*, March to May.

Growth Rings

A sample of clams consisting of different size-groups ranging from 7 mm. to 22 mm. was carefully studied to ascertain the significance of certain definitely marked zones and rings on the shells in determining the age, if possible, on this basis. In all the clams above 15 mm. in length there is a distinctly marked ring on the shell as seen from Table VI. This ring occurs at a distance within a range of 9·1 mm. to 12·2 mm. from the umbo. The

TABLE VI

Showing Size of Clams with Position and Number of Rings

Length of the size-group	Width		Extent of zone one from Umbo		Distance of ring one from Umbo	
	Mean	Range	Mean	Range	Mean	Range
7– 8	5·27	5·1– 5·5	..	..	..	..
8– 9	5·37	6·1– 6·7	5·49	5·1–5·7	..	..
9–10	7·02	6·7– 7·3	4·84	4·1–5·7	..	..
10–11	7·66	7·4– 7·9	5·36	4·7–5·9	..	..
11–12	8·25	7·6– 8·6	5·65	4·9–6·8	..	..
12–13	8·98	8·7– 9·4	6·45	6·3–7·1	..	..
13–14	9·75	9·4–10·7	5·24	3·6–6·8	..	..
14–15	10·54	10·0–11·1	5·60	4·1–6·7	..	..
15–16	10·59	10·1–11·2	5·48	4·6–7·1	9·86	9·1–10·9
16–17	11·33	11·1–11·7	5·54	4·9–6·9	10·76	10·3–11·1
17–18	11·95	11·3–12·2	6·31	5·6–7·3	11·10	10·8–11·5
18–19	12·68	12·2–13·6	5·97	5·4–6·6	10·93	10·1–11·7
19–20	13·41	13·0–14·1	6·16	5·4–8·1	11·36	10·4–12·1
20–21	13·77	13·1–14·3	6·73	5·3–7·3	11·30	10·5–12·2
21–22	13·90	..	6·10	5·5–6·7	11·35	10·9–11·8

mean and the range of this distance from the umbo are indicated in the table. That a cessation of growth has occurred during the period of the formation of the ring is certain. From the size-frequency distribution it is seen that the clams of the first year-class complete about 11 months of life by about November and merge with the larger clams. It is quite possible that this ring corresponds to the period, November to December, during which the environmental conditions are unfavourable, as will be discussed later.

The growth of the shell up to the formation of the ring referred to is not uniform. There are two distinct zones invariably met with in all the clams examined (Plate V). The extent of zone one from the umbo ranges from 3·6 mm. to 7·1 mm. Distinct zonation is seen in clams from 8 mm. in length which is attained by about April when the clams are about four months old. It may be observed from the graph that up to April or May very high temperatures are recorded, which seem to be not congenial for rapid growth. The wider extent of zone 2, as contrasted with zone 1, shows that the period in which it is formed is more favourable for growth than that in which the zone 1 is formed. The period of formation of zone 2 corresponds roughly to June–October, during which the water temperatures are moderate (28·2° C.–29·2° C.). The very great variability of the extent of zone 1 is due to the fact that the period of spawning is prolonged and the young ones, which commence appearing from January, continue to occur till about March or April. If this zonation has taken place by about April or May in young clams due to unfavourable environmental conditions, it is evident that the extent of the zone does not remain the same because of the variation in the age of the different individuals.

The Density of Populations

In each sample of clams obtained from one square-foot area, the young ones up to 11 mm. and the adult clams above 12 mm. in length are shown separately (Table VII) for a period of about one year. It may be seen that from 12th February to 7th May 1952 the density of the adult clams remains almost the same in all the samples. In the sample examined on 30th June 1952, there was a marked fall in the population of the adults. It may be recalled that the period, May–June, registered a heavy mortality of the adults, as described elsewhere. From 9th June to 10th November 1952 a steady decline in the number of the adults was noticed. Fairly large numbers of young ones of gradually increasing sizes are also present during this period. From 21st November to 20th January 1953, the number of young clams decreases and that of the adult clams increases. From the size-frequency diagrams it is clear that the new year-class grows sufficiently large to merge

TABLE VII

Showing the Density of Populations of Young and Adult Clams per Square Foot Area in Different Samples

Date	Young clams (1 mm.–11 mm.)	Adult clams (12 mm.–22 mm.)	Total
12- 2-1952	..	423	423
22- 2-1952	..	419	419
3- 3-1952	..	405	405
13- 3-1952	..	434	434
3- 4-1952	..	473	473
15- 4-1952	..	397	397
26- 4-1952	..	448	448
7- 5-1952	..	437	437
30- 5-1952	..	376	376
9- 6-1952	237	238	475
20- 6-1952	121	254	375
30- 6-1952	277	162	439
10- 7-1952	146	264	410
31- 7-1952	182	184	366
9- 8-1952	206	172	378
19- 8-1952	55	130	185
29- 8-1952	98	193	290
11- 9-1952	115	170	285
30- 9-1952	96	179	275
10-10-1952	89	160	249
21-10-1952	112	150	262
30-10-1952	120	140	260
10-11-1952	150	130	280
21-11-1952	22	258	280
29-11-1952	14	286	300
23-12-1952	..	260	260
20- 1-1953	..	270	270
31- 1-1953	5	305	310
19- 2-1953	46	294	340

with the older clams by about November. In January and February 1953, a small number of younger clams have entered the populations. The number of the adult clams are fairly large, as in the two previous months. The table thus shows the period of mortality of the adult clams, as also the period when the younger clams grow large enough to merge with the adults.

General Considerations

That growth and breeding in marine animals are influenced to a large extent by fluctuations of environmental factors like temperature and salinity is well known. In the temperate waters, changes in temperature in summer and winter are very marked, with the result that there is more rapid growth in the former and less or negligible growth in the latter. The variations in growth rate leave an impression on the shell in the form of annual rings, the measurements of which are helpful in determining the age of the clams. McMillin (1924) and Weymouth *et al.* (1925) in the Pacific Razor clam, *Siliqua patula,* Orton (1926) in the European cockle, *Cardium edule,* Fraser and Smith (1928) in the butter clam, *Saxidomus giganteus,* Weymouth (1923) in Pismo clam, *Tivela stultorum,* Newcombe (1936) in *Mya arenaria,* and Quayle (1952) in *Venerupis pullastra* have proved the validity of the rings for measuring annual growth. In tropical waters, however, where changes in temperature in summer and winter are negligible, annual rings of the kind met with in temperate forms are not usually found. That certain disturbances in living molluscs also cause the formation of rings has been proved by Orton (1926). Rao (1952), in *Katelysia opima,* has found certain deeply marked rings in a majority of the shells in samples from Adyar and described them as disturbance rings, indicating periods of arrested growth that occur year after year from August to December, when there is a fall in salinity of the waters. He has found a maximum number of three rings in the largest clams examined and correlated the data by the measurement of the rings with the results from length-frequency method of examination of random samples collected from month to month. In *Donax* only one deeply marked ring is observed and it has been interpreted that it is formed due to unfavourable conditions prevailing in November–December, when the clams are nearly one year old. The bay is rough during these months due to the north-east monsoon and the extreme disturbance caused to the clam beds probably leads to a reduced level of nutrition, resulting in the formation of a ring. Further, extreme variations in temperature also seem to leave an impression on the shell, as explained in the formation of zones 1 and 2. Belding (1910) and Coe (1947) have recorded post-spawning cessation of growth marked by the formation of rings on the shell in *Pecten* and *Tivela* respectively. There seems to be no cessation of growth after the period of spawning in *Donax* as observed by Rao (1952) in *Katelysia,* Belding (1912) in *Venus* and Loosanoff and Nomejko (1949) in *Ostrea.*

The species of *Donax* described here is similar in its habits to the bean-clam, *Donax gouldi,* of the coasts of California, where it is collected for the preparation of broth. *Donax gouldi* is much esteemed for this purpose and is said to be unexcelled by any other bivalve. The Indian and the Californian species are subject to resurgent population increases and form solid beds of several layers deep in the sandy shores of the surf-line. Proper utilization of the species can open a new small industry.

In a littoral species, whose developmental stages are subject to the chance drifting by the currents to establish new beds at times far away from the original beds, the usual methods of conservation of the beds may after all not yield fruitful results. In enclosed backwaters, in which the young ones usually settle on the very same beds where the adults exist, regulated fishing by introducing suitable size limits will be effective in preserving the beds. So far as *Donax cuneatus* is concerned there is greater need for exploitation and utilization than for introducing methods of conservation. They are at present fished in small quantities all round the year and more particularly during the period of north-east monsoon, November–December, when general fishing of food fishes is rather poor. If the fishing is less intensive in the months before the spawning period rather than in the period immediately following it, the clams are given a chance for breeding before they are removed from the beds. If a close season is to be observed a period of three to four months from December to February or March will be most suitable.

SUMMARY

Spawning commences in *Donax cuneatus* of Palk Bay in January and lasts till about April. Young ones which appear from February onwards grow to the adult size of about 14 mm. in length by November and merge with the older clams. Most clams seem to die during the second year of their life, after attaining an average length of about 19 mm.

Sexual maturity is attained when they are 12 mm. to 13 mm. in length and ten months old. They spawn for the first time when they are one year old. They do not seem to spawn more than twice during their life-time.

Mortality of the adult clams was highest during October–November and June–July, which are preceded by the highest salinity and temperature conditions of the inshore waters respectively.

Certain distinct rings and zones on the shells indicate that growth is not uniform throughout the year. Cessation of growth, as indicated by the formation of the ring when the clams are about one year old, seems to be due to unfavourable environmental conditions during the period November–December. Variations in temperatures also seem to leave an impression on the shell in the form of zones.

A period of mortality of the adult clams in June–July and a period when the young clams grow large enough to merge with the adults in November, are clearly indicated by the fluctuations in the density of populations.

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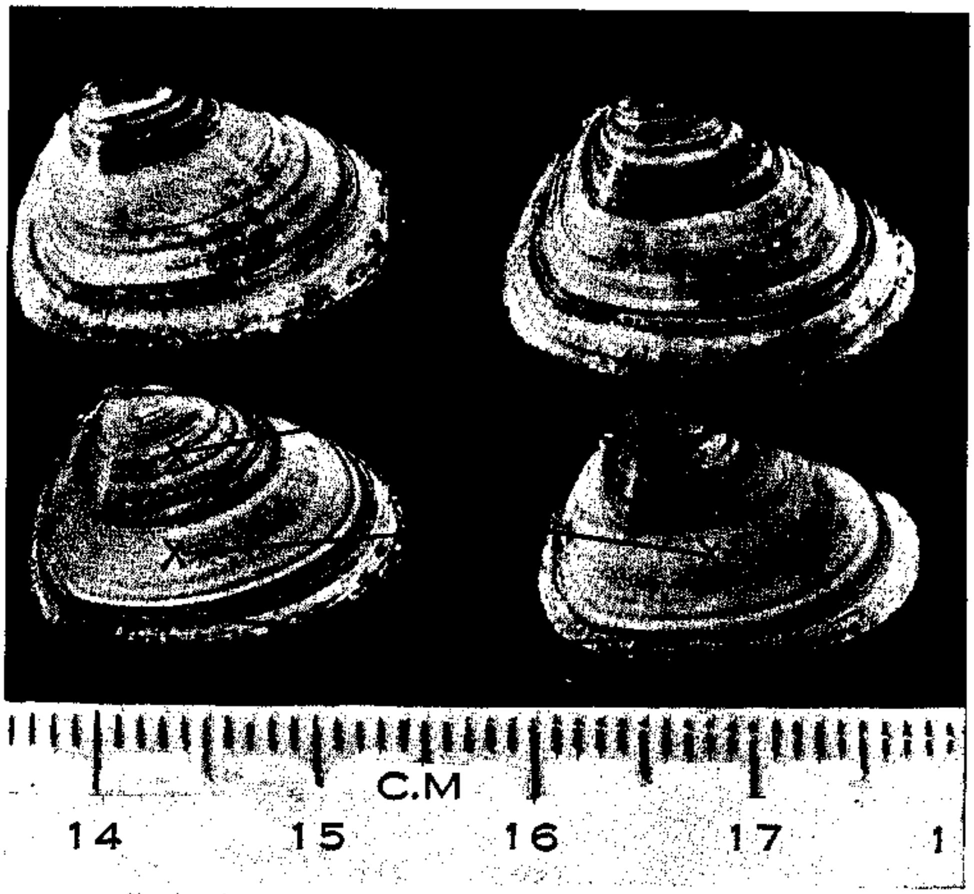
STUDIES ON THE GROWTH OF WEDGE CLAM, *DONAX* (*LATONA*) *CUNEATUS* LINNÆUS, OF THE PALK BAY



Showing the zonation and formation of growth rings in *Donax cuneatus*
Z. 1 : Zone 1 ; Z. 2 : Zone 2 ; R. 1 : First Ring