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THE RATE OF GROWTH OF SPAT AND YEARLINGS OF THE PEARL OYSTER *PINCTADA RADIATA* (LEACH) OF BAHRAIN WATERS

K. NAGAPPAN NAYAR AND MOHAMMED AL-RUMAIDH

Bahrain Centre for Studies and Research, P.B. No. 496, Manama, Bahrain

ABSTRACT

Two batches of pearl oyster spat were collected from one of the offshore pearl banks on 16th November 1987 and 1st December 1987 and their linear measurements were recorded. They were put in two separate cages and reared suspending the cages at No. 3 Beacon. Periodical measurements were recorded of the spat and their rate of growth was studied. This preliminary study has indicated that the spat grows to a length of about 45 mm within one year and 70 mm approximately in 2 years. Rate of growth appears to be slightly faster in Bahrain waters, compared to the observations made in India and Japan. Although the data have been analysed mainly on dorso-ventral measurements, the average growth in width, hinge length and thickness have also been given. The temperature, salinity and pH of the waters of the pearl banks during the period of observation have been recorded.

INTRODUCTION

PEARL fishing has been going on in Bahrain waters from time immemorial and the pearls obtained from the oysters of the area were considered to be far superior than those harvested from the nearby pearling countries. Pearl diving was the profession for a very large number of Bahrainis till the advent of oil. A switch over from the profession took place from then on and most of the divers got more comfortable shore jobs, with better remuneration, due to the establishment of oil companies. This change made all the pearl divers abandon their age old traditional occupation and taken to more lucrative jobs available on shore, which ultimately led to the natural death of pearl fishing in Bahrain by early sixties.

In 1985 the Bahrain Centre for Studies and Research in its regular research programme included a feasibility study to find out the present status of the pearl oyster beds with a view to ascertaining the possibility of reviving the age old traditional pearl fishery of Bahrain. This programme was initiated

by Allouch (1985) and the preliminary investigations carried out by him were published in the form of a report. Under this programme, research on various aspects of pearl oysters are being pursued and the study on the early rate of growth of spat and yearlings of the pearl oyster *Pinctada radiata* (Leach) is one amongst them.

By scanning the available literature, it is seen that not much of scientific research has been carried out on the biology or growth of the pearl oysters of this region. Bowen (1951), Belgrave (1960, 1968), Belgrave, J.H.D. (1975), Lorimer (1951), and Datta and Nugent (1985) are some of the important authors who have published very valuable information regarding the details of fishery, the exact location of the different pearl oyster beds, the number of divers engaged in the fishery, etc.

Chidambaram (1958) as given by Devanesan and Chacko (1958) took a consignment of pearl oysters from Bahrain in 1950 to Tuticorin and Krusadai Island in India to repopulate, barren pearl oyster beds of that region. In his report, he has given some general information regarding the pearl fishery in the Arabian Gulf and the sea conditions such as temperature, salinity, etc. of the Bahrain waters. Vousden (1985 A) has mentioned that the trade about 80 years ago was valued at B.D. 500,000 and provided employment for 20,000 men. He has also mentioned that in 1915 it was the premier industry of the Gulf, employing 4,500 boats with over 74,000 men. His report is rather a review with some suggestions than a feasibility study as no actual work has carried out by him. Vousden (1985 B), along with some other scientists of the Bahrain Centre for Studies and Research surveyed a few offshore oyster beds for eight days in August, 1987. Mohammad (1972, 1976) from Kuwait has studied the infestation of pearl oysters by a new species of *Polydora* and also workedout the relationship between biofouling and growth of the oysters found in the coast a waters of Kuwait. Almatar *et al.* (1983) have given an account of the pearl oyster fishery of Kuwait and have also studied the size composition of the oysters collected from the market.

In India, Sri Lanka, Japan and Australia, earlier workers have carried out extensive studies on various aspects of biology, physiology, etc. on pearl oysters dating back from the beginning of this century. Herdman (1903) carried out elaborate work including biology of the pearl oysters found in the Sri Lanka Coast. His work was followed by Hornell (1922), Devanesan and Chidambaram (1956), Gokhale *et al.* (1954), Narayanan and Michael (1968), Pandya (1975), Alagarswami and Chellam (1977), Nayar *et al.* (1978) and Chellam (1978). Similar studies have also been made in Japan by Kobayashi (1948) and Kobayash and Tabota (1949) and by Nicholls (1931) in Australia.

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Material and Methods

One sample of spat and oysterlings numbering 29 from Bl Jaal (26° 38′ 89″ N - 50° 59′ 80″ E) was collected on 16th November 1987 and the length, width, hinge length and thickness of the oysters were measured. The sample was grown in a cage with mesh size of 3 mm and suspended at No. 3 Beacon

(26°3' 52" N - 51° 33' 00" E). As the sample size was too small, one more sample of spat was collected from the same bed on 25th November 1987 and all the measurements as mentioned above were taken and the oysters reared at No. 3 Beacon. It so happened that on 1st December 1987 the second cage was found damaged and it was possible to salvage about 50 spat only which were again measured and the experiment was continued from that day onwards considering the sample as a fresh one. Spat belonging to both the batches were measured at periodical intervals.

Rate of growth of oysters has been studied by earlier workers using different methods. Some have followed the length frequency method by examining the random samples (Herdman, 1903; Devanesan and Chidambaram, 1956). Some others have tried to interpret the growth, using the growth rings on the shells (Ghokhale *et al.*, 1954; Narayanan and Michael, 1968; Pandya, 1975). A few others have taken the periodic measurements of the same oysters kept in sandwich-type frame nets or cages (Chellam, 1978 ; Appukuttan, 1987).

Growth rate was determined by the size frequency method. The greatest distance from the hinge to the ventral margin of the valves (DVM) was taken as the length, the antero-posterior measurement as width, the total length of the hinge as the hinge length and the maximum distance between the two valves as shell depth or thickness. Although the idea was to take the measurements at regular intervals, due to various reasons it was found difficult, but at the same time they were taken out, cleaned and measured as and when it was possible. The measurements of the oysters were taken with sliding calipers correct to 0.1 mm and were grouped in sizes with class interval of 5 mm. The salinity, temperature and pH of the water of the pearl banks were regularly recorded to ascertain their effect, if any, on the growth and breeding of the oysters.

RESULTS

Growth in dorsoventral measurements

The sample No. 1, taken on 16th November 1987 (Fig. 1 A1, Table 4) indicates the presence of three modes at 5-10 mm, 15-20 mm and 30-35 mm. This shows that they belong to three different broods, setting at three different periods. The next measurement of the spat was taken on 21st December 1987, after a lapse of 35 days. It is seen from the histogram (Fig. 1 A2) that the mode at 30-35 mm seen on 16th November 1987 has moved to 35-40 mm and the other two modes have merged and formed a single mode at 15-20 mm. The next histogram dated 29th February 1988 (Fig. 1 A3) shows two modes at 45-50 mm and 25-30 mm and the subsequent one dated 3rd April 1988, after a lapse of 34 days, shows the modes at 50-55 mm and 30-35 mm (Fig. 1 A4). The measurement taken on 7th July 1988 (Fig. 1 A5) after 95 days, shows the two modes at 55-60 mm and 45-50 mm and also shows a third mode at 35-40 mm. The next reading taken on 20th October 1988 (Fig. 1 A6) after an interval of 105 day, shows the modes at 60-65 mm and 45-55 mm. As the cage was damaged, all the oysters were lost and the experiment was terminated.

The seed oysters measuring 5-10 mm on 16th November 1987 have grown to 25-30 mm by 29th February 1988 after a period of 105 days. They attained a size of 35-40 mm on 7th July 1988 after a total period of 234 days. Within a period of 339 days, they were all in the size range of 45-55 mm group. This shows that a spat of 5 mm has grown to a size of 50 mm within a period of 11 months. Considering that it takes 35 days for a spat of 5 mm to grow to a size of 15 mm (Fig. 1 A1, A2), it can be presumed that a spat which settles normally at less than 1 mm would not have taken more than 15 days to attain the size of 5 mm. (On a subsequent observation on spat collection carried out in August 1989 by putting

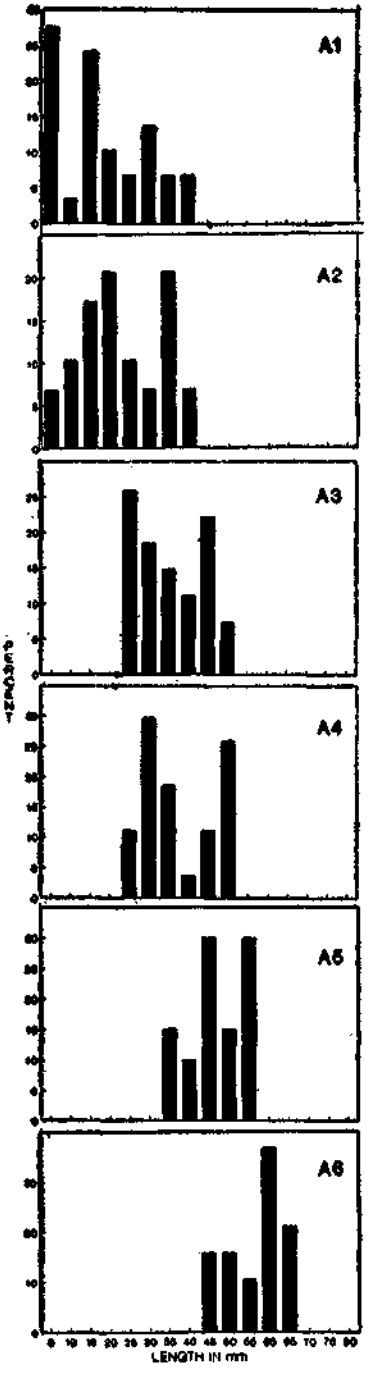


FIG. 1. Size frequency histograms of the 'A' series of oyster spat measurements recorded on 16-11-1987, 21-12-1987, 29-2-1988, 3-4-1988, 7-7-1988 and 20-10-1988.

TABLE 1. *'A' series — Variables such as maximum size, minimum size, average size, etc. for length, width, hinge length and depth of the spat of* Pinctada radiata

Variable	length	width	hinge	depth
A1 16th November 1987 Sample size : 29				
Average (mm) ..	20.8	20·0	22.7	5.8
Median (mm) ..	17.3	17.3	21.4	5.1
Mode (mm) ..	7.1	17.1	40.2	2.9
Standard deviation	11.3	10.8	11.3	3.1
Standard error ..	2.1	2.0	2.1	0.6
Minimum (mm) ..	5.1	5.1	5.4	1.7
Maximum (mm) ..	41.9	41.3	40.9	11.8
Range (mm) ..	36.8	36.2	35.5	10.1
A2 21st December 1987 Sample size : 29				
Average (mm) ..	25.1	24.1	27.9	7.0
Median (mm) ..	24.1	21.8	25.3	6.1
Mode (mm) ..	25.1	31.2	39.1	6.1
Standard deviation	10.1	10.2	9.8	3.2
Standard error ..	1.9	1.9	1.8	0.6
Minimum (mm) ..	6.9	6.3	8.5	1.9
Maximum (mm) ..	43.4	42.2	42.3	12.9
Range (mm) ..	36.5	35.9	33.8	11.0
A3 29th February 1988 Sample size : 27				
Average (mm) ..	37.8	35.0	36.5	11.0
Median (mm) ..	37.1	34.7	36.3	10.9
Mode (mm) ..	35.1	25.1	35.1	7.2
Standard deviation	8.5	8.0	6.8	3.1
Standard error ..	1.6	1.5	1.3	0.6
Minimum (mm) ..	26.1	23.3	24.3	6.4
Maximum (mm) ..	51.8	46.7	49.1	17.7
Range (mm) ..	25.7	23.4	24.8	11.3
A4 3rd April 1988 Sample size : 27				
Average (mm) ..	39.6	37.4	38·2	12.2
Median (mm) ..	38.5	37.2	37.4	11.8
Mode (mm) ..	34.1	37.7	33.4	8.1
Standard deviation	8.7	8.6	6.7	3.4
Standard error ..	1.7	1.6	1.3	0.6
Minimum (mm) ..	26.4	24.9	27.1	8.1
Maximum (mm) ..	53.8	51.3	50.4	17.9
Range (mm) ..	27.4	26.4	23.3	9.8

A5 7th July 1988	Sample size : 20			
Average (mm) ..	49.1	46.3	43.7	19.0
Median (mm) ..	49.1	46.6	44.5	19.5
Mode (mm) ..	36.8	45.3	47.8	16.9
Standard deviation	7.1	7.6	6.1	3.1
Standard error ..	1.6	1.7	1.4	0.7
Minimum (mm) ..	36.8	32.4	32.8	12.3
Maximum (mm) ..	58.7	56.8	56.7	23.7
Range (mm) ..	21.9	24.4	23.9	11.4

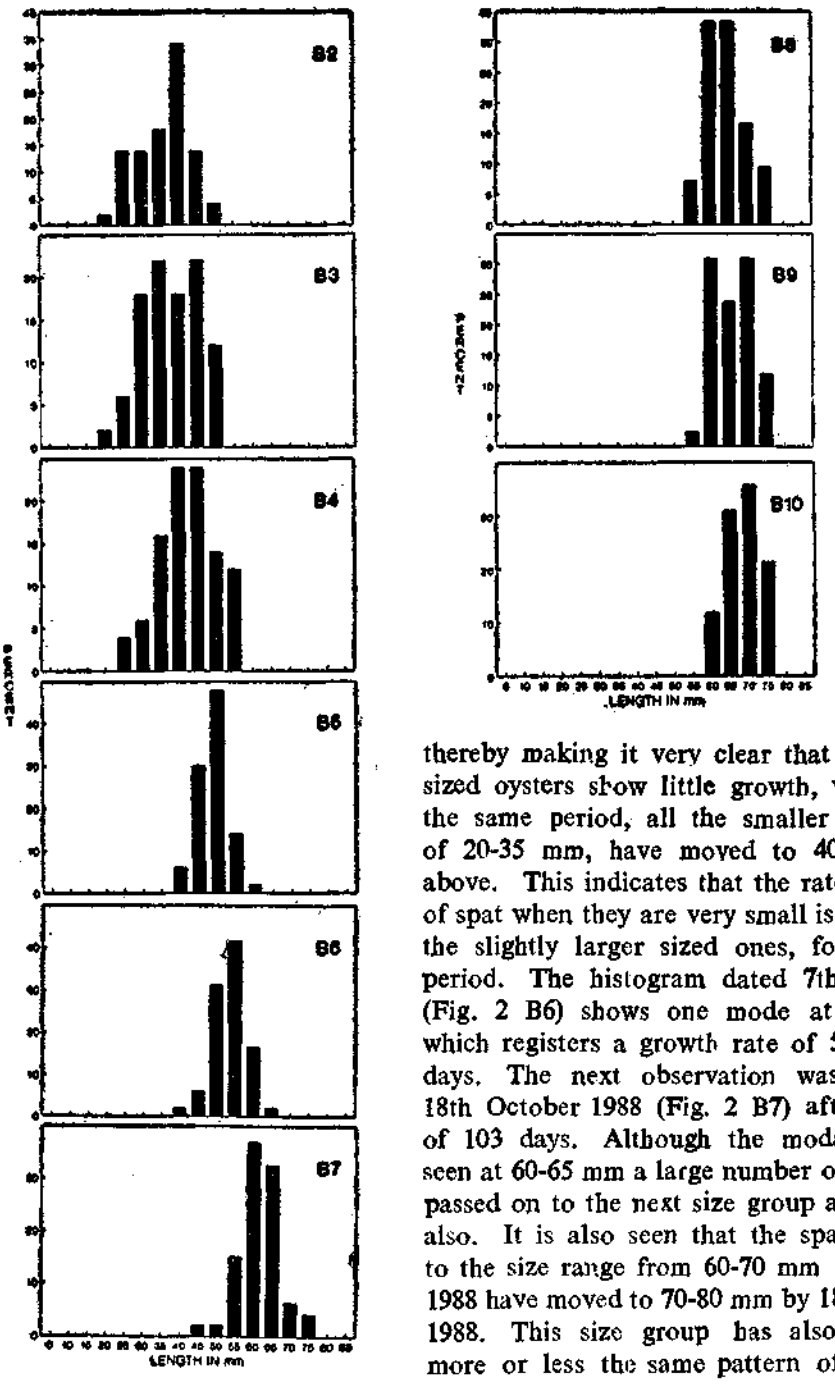
A6 20th October 1988	Sample size : 19			
Average (mm) ..	59.0	52.6	46.3	24.3
Median (mm) ..	62.1	53.1	47.1	24.9
Mode (mm) ..	62.1	53.1	46.9	24.6
Standard deviation	6.8	7.2	5.9	4.7
Standard error ..	1.6	1.7	1.3	1.1
Minimum (mm) ..	45.3	39.7	34.6	12.7
Maximum (mm) ..	69.2	64.3	55.3	35.4
Range (mm) ..	23.9	24.6	20.7	22.7

spat collectors and watching the spat settlement and their growth, it was observed that about 14 days time was required for the spat to attain a size of 5 mm after setting). Following the rate of growth of the smallest spat and presuming that it is the same spat always measuring the smallest throughout the period of observation (Table 1), it is seen that the spat measuring 5.1 mm on 16th November 1987 has grown to 26.1 mm by 29th February 1988 registering a rate of growth of 22.1 mm within a period of 105 days. In the last measurement (*i.e.*) 20th October 1988 it measured 45.3 mm. Adding 2 weeks time which is the time required for the spat to reach a size of 5 mm after setting, to the total number of observation of 339 days, it is seen that the spat would have taken 353 days to attain a size of 45 mm after setting. Hence within a period of less than one year the pearl oyster spat will reach a size of 45 mm. From the above observations it is presumed that the setting of the spat would have taken place some time by the end of October 1987. Algarswami *et al.* (1983) have stated that the pelagic larval phase of the pearl oyster appears to be similar, both in Japan and in India, lasting about 20 days, with setting of spat taking place between 20 to 25 days. Considering the pelagic life of the larvae to be about three weeks, it can be said that the spawning of the mother oyster would have taken place some time during the first week of October 1987.

The mode at 30-35 mm seen on 16th November 1987 has shifted to 35-50 mm, 45-50 mm, 50-55 mm, 55-60 mm and 60-65 mm within a period of 35, 70, 34, 95 and 105 days interval respectively. This has registered a total growth rate of 30 mm for oyster spat of 30 mm size group within 11 months. Similarly the smallest spat of 5 mm on 16th November 1987 has grown to a size of 45 mm on 20th October 1988 thereby recording to an increase in length of 40 mm during the same period of 11 months.

From the above observations (Table 4) it could be inferred that to attain a size of 15 - 20 mm the spat take about 50 days, 25-30 mm in 4 months, 30-35 mm in 5 months, 40-45 mm in 8 months and 45-50 mm in about one year.

In the next sample (Sample No. 2, Fig. 2 B2, B3) it is seen that the mode at 40-45 mm on 1st December 1987 has shifted to 45-50 mm on 6th of January 1988 within a period of 36 days. In the same histogram (B3) another mode at 35-40 mm is also seen which may be the result of the smaller spat ranging in size between 25-35 mm found in the previous histogram (B2) growing a bit faster. The histogram on 29th February 1988 (Fig. 2 B4) shows only one mode at 40-50 mm size group being the result of 54 days growth. It is seen that the oysters measuring 50-55 mm on 6th January 1988 have approximately grown in length by 5 mm and reached the size interval of 55-60 mm within a period of 54 days. The observation made on 4th April, 1988 (Fig. 2 B5) after 34 days interval, shows the modal value at 50-55 mm. It is also seen that only very few oysters measuring 55-60 mm on 29th February 1989 have grown to the next size group of 60-65 mm by 4th April 1988 mm



thereby making it very clear that the larger sized oysters show little growth, whereas for the same period, all the smaller sized spat, of 20-35 mm, have moved to 40 mm and above. This indicates that the rate of growth of spat when they are very small is faster than the slightly larger sized ones, for the same period. The histogram dated 7th July 1988 (Fig. 2 B6) shows one mode at 55-60 mm which registers a growth rate of 5 mm in 95 days. The next observation was made on 18th October 1988 (Fig. 2 B7) after a period of 103 days. Although the modal value is seen at 60-65 mm a large number of spat have passed on to the next size group at 65-70 mm also. It is also seen that the spat belonging to the size range from 60-70 mm on 7th July 1988 have moved to 70-80 mm by 18th October 1988. This size group has also registered more or less the same pattern of growth as

FIG. 2. Size frequency histograms of the 'B' series of oyster spat measurements recorded on 1-12-1987, 6-1-1988, 29-2-1988, 4-4-1988, 7-7-1988, 18-10-1988, 6-12-1988, 30-1-1989 and 22-5-1989.

was observed for the previous period. The next reading on 6th December 1988 (Fig. 2 B8) after a period of 49 days shows the modal value at 60 mm to 70 mm thereby registering very little growth during that period.

It is seen (Fig. 2 B7) that the oysters of the size group 75-80 mm on 18-10-1988 after a period of 49 days, on 6th December 1988 (Fig. 2 B8) did not show any appreciable growth. After a further period of 55 days, *i.e.* on 30th January 1989 (Fig. 2 B9) some of the oysters have moved from 65-70 mm to 70-75 mm thereby showing 2 modes at 60-65 and 70-75 mm. The next reading taken after a period of 112 days on 22nd May 1989 (Fig. 2 B10) shows that all oysters fall within the size range of 60 mm to 80 mm with the modal value at 70-75 mm thereby indicating a marginal growth of 1 or 2 mm during this period. As this histogram (Fig. 2 B10) is showing only one mode, it is clear that spat ranging in size of 65-70 mm in the previous histogram (Fig. 2 B9) have moved to the next size group and similarly the smaller size group at 60-65 mm have also grown to the size of 65-70 mm.

From these histograms it is seen that the spat measuring 40-45 mm on 1st December 1987 have grown to a size of 60-70 mm by 6th December 1988 within a period of one year. This shows that a 40 mm oyster will attain a size of 65 mm within a period of one year there by registering a growth of 25 mm. Spat measuring 40-45 mm will be about 8 months old (*vide supra*) and hence we can presume that an oyster attaining a size of about 60-65 mm will be approximately about 1 year and 7 months old. Oysters measuring 70-75 mm may be about 2 years.

Growth in width or anterio-posterior measurement

Oysters having an average width of 20 mm on 16th November 1987 have grown to 24.1 mm, 37.3 mm, 46.3 mm and 52. 6 mm in 35, 139, 234 and 339 days thereby registering a

TABLE 2. *'B' series — Variables such as maximum size, minimum size, average size, etc. for length, width, hinge length and depth of spat* Pinctada radiata

Variable	length	width	hinge	depth
B2 1st December 1987	Sample size : 50			
Average (mm) ..	38.3	36.0	38.2	11.2
Median (mm) ..	40.1	36.8	39.0	11.7
Mode (mm) ..	37.5	37.5	39.5	13.5
Standard deviation	6.9	6.3	5.9	2.4
Standard error ..	0.9	0.9	0.3	0.3
Minimum (mm) ..	24.3	20.2	21.4	6.7
Maximum (mm) ..	51.2	46.2	49.4	15.3
Range (mm) ..	26.9	26.0	28.0	8.6
B3 6th January 1988	Sample size : 50			
Average (mm) ..	40.5	37.2	38.2	12.9
Median (mm) ..	41.7	38.0	38.1	12.9
Mode (mm) ..	48.9	44.7	34.4	13.2
Standard deviation	7.5	6.6	5.6	4.7
Standard error ..	1.1	0.9	0.8	0.7
Minimum (mm) ..	24.8	20.7	27.4	7.7
Maximum (mm) ..	53.2	48.3	50.3	40.2
Range (mm) ..	28.4	27.6	22.9	32.5
B4 29th February 1988	Sample size : 50			
Average (mm) ..	44.7	42.1	40.9	14.1
Median (mm) ..	45.0	43.0	42.1	14.4
Mode (mm) ..	41.7	43.2	42.3	15.4
Standard deviation	7.4	6.5	5.6	2.7
Standard error ..	1.1	0.9	0.8	0.4
Minimum (mm) ..	25.1	25.1	27.9	8.7
Maximum (mm) ..	58.2	53.7	51.9	18.7
Range (mm) ..	33.1	28.6	24.0	10.0
B5 4th April 1988	Sample size : 50			
Average (mm) ..	51.0	47.6	45.6	16.9
Median (mm) ..	51.4	48.5	45.3	16.9
Mode (mm) ..	55.3	44.2	47.3	16.8
Standard deviation	4.3	4.2	4.1	1.8
Standard error ..	0.6	0.6	0.6	0.3
Minimum (mm) ..	40.2	35.5	35.9	12.1
Maximum (mm) ..	60.1	55.1	56.7	20.5
Range (mm) ..	19.9	19.6	20.8	8.4

B6 7th July 1988	Sample size : 48			
Average (mm) ..	56.0	52.2	47.9	19.8
Median (mm) ..	56.6	52·8	48.4	20.2
Mode (mm) ..	62.8	53.8	50.1	22.7
Standard deviation	5.0	5.3	4.1	2.3
Standard error ..	0.7	0.7	0.6	0.3
Minimum (mm) ..	40.9	36·8	37.0	12.8
Maximum (mm) ..	65.8	62.3	58.7	23.7
Range (mm) ..	24.9	25.5	21.5	10.9

B7 18th October 1988	Sample size : 46			
Average (mm) ..	63.8	57.4	50.0	23.4
Median (mm) ..	64.2	57.4	50.1	23.6
Mode (mm) ..	70.2	54.6	49.9	24.6
Standard deviation	5.6	4.5	3.9	2.5
Standard error ..	0.8	0.7	0.6	0.4
Minimum (mm) ..	47.8	43.2	38.4	15.6
Maximum (mm) ..	78.3	69.1	59.3	27.5
Range (mm) ..	30·5	25.9	20.9	11.9

B8 6th December 1988	Sample size : 42			
Average (mm) ..	66.9	61.2	52.0	25.0
Median (mm) ..	67.2	60.4	51.5	25.2
Mode (mm) ..	64.7	57.3	50.7	22.6
Standard deviation	5.2	5.0	4.0	2.4
Standard error ..	0.8	0.8	0.6	0.4
Minimum (mm) ..	55.3	49.9	61.8	30.6
Maxiumm (mm) ..	78.5	72.4	61.8	30.6
Range (mm) ..	23.3	22.5	20.7	13.3

B9 30th January 1989	Sample size : 42			
Average (mm) ..	68.7	62.9	53.4	26.0
Median (mm) ..	67.7	62.3	53.8	26.3
Mode (mm) ..	67.2	62.3	53.7	27.3
Standard deviation	5.3	4.8	4.4	2.1
Standard error ..	0.8	0.7	0.7	0.3
Minimum (mm) ..	59.3	55.1	46.2	22.8
Maximum (mm) ..	78.8	72.8	68.3	31.4
Range (mm) ..	19.5	17.7	22.1	8.2

B10 22nd May 1989	Sample size : 42			
Average (mm) ..	70.4	64.8	53.2	27.2
Median (mm) ..	70.5	64.2	52.8	27.3
Mode (mm) ..	79.9	61.2	50.2	25.1
Standard deviation	4.9	4.9	3.6	2.2
Standard error ..	0.8	0.8	0.6	0.3
Minimum (mm)	62.1	56.1	47.1	23.4
Maximum (mm) ..	79.9	74.6	62.9	31.8
Range (mm) ..	17.8	18.5	15.8	8.4

growth increment of 32.6 mm for a period of about 11 months (Fig. 3).

In Fig. 4, oysters with the average width of 36.0 mm have grown to 42.0 mm in 90 days, 52.2 mm in 219 days, 61.2 mm in 371 days and 64.8 mm in 538 days. For a period of about 11 months they have a growth of 21.4 mm and for 539 days 28.8 mm. It is also seen that the rate of growth is faster when they are small and it decreases as they grow older. For the same period of about 11 months, spat measuring an average size of 20 mm have grown by 32.6 mm (Table 1) while as spat of average width of 36.0 mm have shown a rate of growth of 21.4 mm (Table 2) only for the same period.

The pattern of growth in both the cases is comparable. In relation to the rate of growth of the shell length, the breadth also increases, but as the oysters grow older the breadth does not show as much growth as the shell length.

Growth in hinge length

In Fig. 3 and 4, it is seen that the hinge growth is faster when they are very small and it considerably slows down as they attain a length of about 36 mm.

Growth in shell depth or thickness

In both the figures (Fig. 3 and 4) the growth in depth of the shell is comparable. Fairly good relationship is exhibited between the growth in length and the increase in depth. Throughout the period of observation there has been an increase in depth and it slows down as the oysters grow older.

Temperature, salinity and pH

The monthly values of temperature, salinity and pH recorded from the pearl banks are given in the Table 3. It was observed that spawning had commenced during June as the water temperature was increasing and continued throughout the summer months and also

hereafter upto October when the temperature began to fall. The growth rate of the pearl oysters is faster during the months June-October than in other months. The salinity fluctuated from 39.0 to 44.7 ppt, but with the data available it is not possible to say whether it had an effect on spawning. The pH did not show much fluctuation and it varied from 8.1 to 8.3 and it cannot be said whether it has any effect on spawning. But it is well known that in all the induced spawning experiments the temperature, pH and salinity play an important part and by manipulating one or more, the oysters could be induced to spawn (Algarswami *et al.*, 1983). Hence in the natural environment also they would have been responsible for spawning, about which in the present study, due to lack of data, it is not possible to make any comment.

Discussion

The fluctuations of environmental parameters such as temperature, salinity, pH, etc. influence to a large extent the growth and breeding of marine animals. The changes in temperature in summer and winter are well marked in the temperate waters, with the result there is more rapid growth during the former and negligible growth in the latter period. The variation in growth rate leaves an impression on the shell in the form of annual rings, the measurements of which are helpful in determining the age of some of the bivalves. In the pearl oysters of the Bahrain waters, many rings are formed in quick succession, with the result it is found difficult to interpret the age of the oysters based on the present study.

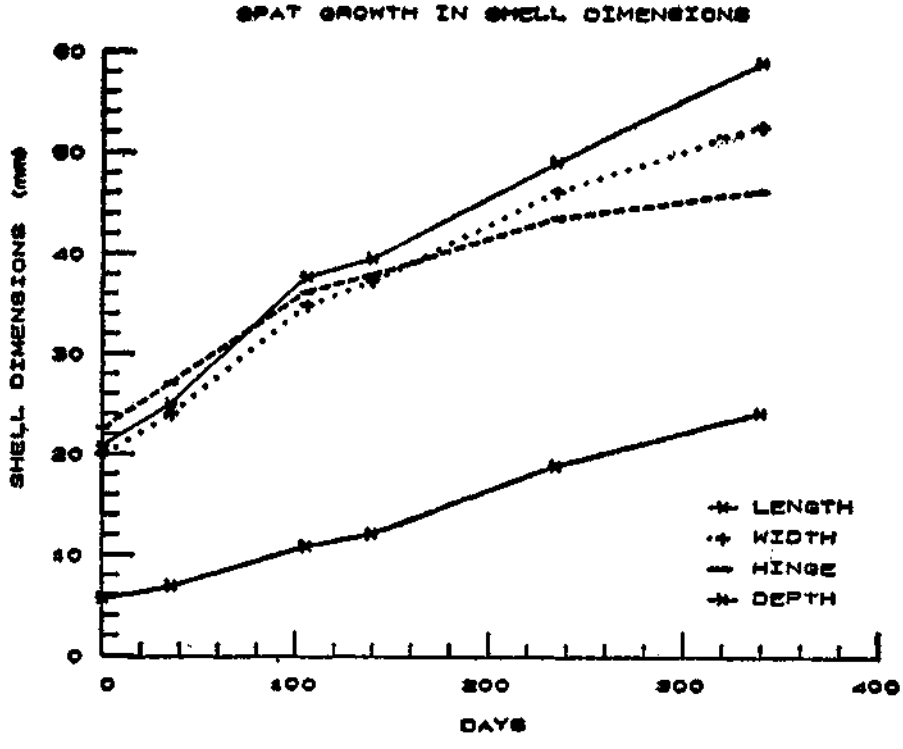


FIG. 3. The average values of the shell length, width, hinge length and depth of the 'A' series of oyster spat for the period 16-11-1987 to 20-10-1988.

In a littoral species, the developmental stages of which are subject to the chance drifting by the currents, it is always better to provide appropriate spat collectors at suitable places and collect large number of spat, which otherwise would have perished, and put them in some of the oyster beds where spat setting would not have taken place due to the vagaries of the current movement. Mahadevan and Nayar (1976), stated that spat setting may not take place at times in the natural beds and it is better to resort to oyster spat collection by putting up suitable spat collectors near the sea surface at suitable places during the spawning season. This will be an ideal method to repopulate and make some of the thinly populated oyster beds more productive in future. The present study has given an idea about the spawning season and also the early rate of growth of the pearl oyster spat which will help us in putting suitable spat collectors at the appropriate time and collecting a large number of spat for sea ranching purposes.

Korringa (1953) states that the shell growth is limited to warm months, at least in temperate regions as this is, like any other activities of the oyster, dependent upon water temperatures. Kobayashi (1948), as referred by Cahn (1949), observes that in *Pinctada martensii* growth is restricted to the months when water temperatures are high, followed by a period of rest when the temperature drops and the oysters hibernate. Almost all the workers from temperate waters who have studied oysters have found that the growth is confined to the periods when the water temperatures are high. The experimental observations of Loosanoff

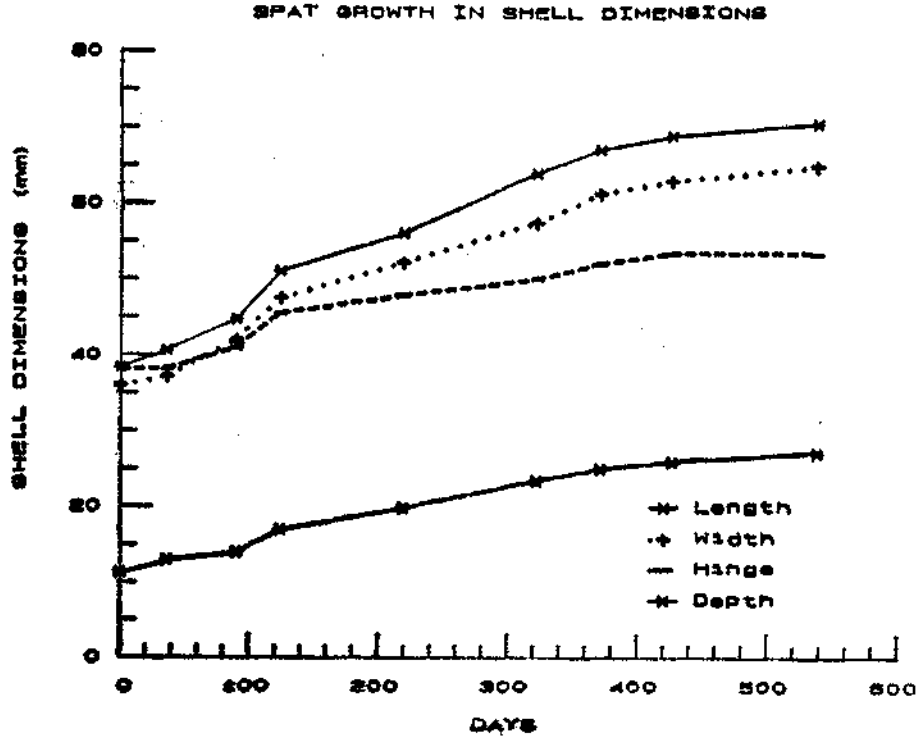


FIG. 4. The average values of shell length, width, hinge length and depth of the 'B' series of oyster spat from 1-12-1987 to 22-5-1988.

1950) and Hopkins (1931) on *Crassostrea virginica* and *Crassostrea gigas* show the extent to which low temperature adversely affects the opening of the valves and the circulation of water• current to secure the organisms forming the food of the oysters. The rate of growth is dependent not only upon the availability of food in the environment, but also upon the ability of the organism to secure it. Very low temperature conditions in winter either considerably slacken or prevent water circulation resulting in very poor or altogether no growth in the temperate region. As the temperature in Bahrain waters vary only from 15.2 to 31.8°C, the growth is not affected much and no appreciable difference in growth is observed here during different seasons.

TABLE 3. *The average monthly temperature (°C), salinity (‰) and pH of the waters from the pearl beds Bahrain Coast during July 1987 to June 1989*

Month	Temperature	Salinity	pH
July 1987 ..	—	40.2	—
Aug. ..	31.5	42.0	—
Sept. ..	31.8	42.0	—
Oct. ..	30.6	44.7	—
Nov. ..	24.3	43.5	—
Dec. ..	21.0	42.0	8.2
Jan. 1988 ..	20.0	39.0	8.1
Feb. ..	22.0	42.0	8.2
Mar. ..	—	44.0	—
Apr. ..	21.0	44.0	8.1
May ..	23.1	44.0	8.1
June ..	28.0	40.0	8.1
July ..	28.0	42.0	8.3
Aug. ..	31.0	40.0	8.2
Sept. ..	31.0	40.0	8.2
Oct. ..	28.5	41.0	8.2
Nov. ..	—	—	—
Dec. ..	20.0	41.0	8.1
Jan. 1989 ..	15.2	41.3	8.2
Feb. ..	16.5	42.0	8.3
Mar. ..	—	—	—
Apr. ..	—	—	—
May ..	26.0	42.0	8.2
June ..	28.3		8.3

From Indian waters, all the workers who have investigated the growth of pearl oysters, have found that the rate of growth of the oyster is fast upto the second or third year and there after it is retarded (Hornell, 1922; Gokhale *et al.*, 1954; Devanesan and Chidambaram, 1956; Narayanan and Michael, 1968). A similar trend of growth for the pearl oysters of Sri Lankan waters has been reported by Herdman (1903). Chellam (1978) has stated that the oysters of the younger size groups show a more progressive growth than the older groups.

Chellam (1978) has observed that an oyster of 34. 1 mm DVM in March 1973 has grown to 46.45 mm by June 1974 showing an average increase of 12.35 mm in one year and four months. Slightly bigger oysters of 35.40 mm size groups showed a growth of 12.40 mm in one year and seven months. In the size groups 50-55 mm and 55-60 mm, the increase was only 1.82 mm and 1.99 mm respectively within a period of one year and four months. He has also observed the rate of growth of spat of *Pinctada fucata* produced in the hatchery and grown in the farm as 47.0 mm at the end of first year, 64.5 mm at the end of second year and 75.0 mm at the end of third year (Chellam, 1987).

In Bahrain waters 40-45 mm oysters on 1st December 1987 (Fig. 2 B2) have grown to 60-70 mm by 6th December '88 within a period of 12 months. It is also observed that it takes about 8½ months to attain a size of 40-45 mm. Hence oysters of 60-70 mm may be approximately 1 year and 8½ months old. As the oysters have grown to 70-75 mm by 22nd May 1989, it could be said that they may be approximately 2 year and 2 months old. This shows a slightly faster rate of growth in Bahrain than what has been observed by Chellam in India.

Gokhale *et al* (1954) have stated that the pearl oyster *Pinctada fucata* of the Gulf of

Kutch, India, grow faster in winter season (November to February) when the temperature of the water varied from 23°C to 27°C and growth ceased during summer months Hornell (1922) has observed that the growth of the pearl oysters is distinctly retarded after the third year and attributed it to the great abundance of encrusting organisms, especially sponges and polyzoans. But Gokhale *et al.* (1954), could not agree to this as they found very good growth in heavily fouled oysters. Mohammed (1976) has observed an inverse correlation between growth of the pearl oysters and diversity of fouling organisms, whatever be the depth.

TABLE 4. *The date of measurements, time interval between each measurements, the progressive total time interval and the modal values of the oyster spat of series 'A' and 'B'*

Date of measurement	Time interval (days)	Progressive time interval (days)	Modal values (mm)
'A' Series			
16-11-'87	(A1) —	—	5-10, 15-20 & 30-35
21-12-'87	(A2) 35	35	15-25 & 35-40
29- 2-'88	(A3) 70	105	25-30 & 45-50
3- 4-'88	(A4) 34	139	30-35 & 50-55
7- 7-'88	(A5) 95	234	35-40, 45-50 & 55-60
20-10-'88	(A6) 105	339	45-55 & 60-65
'B' Series			
1-12-'87	(B2) —	—	40-45
6- 1-'88	(B3) 36	36	45-50 & 35-40
29- 2-'88	(B4) 54	90	40-50
3- 4-'88	(B5) 34	124	50-55
7- 7-'88	(B6) 95	219	55-60
18-10-'88	(B7) 103	322	60-65
6-12-'88	(B8) 49	371	60-70
30- 1-'89	(B9) 55	426	60-65 & 70-75
22- 5-'89	(B10) 112	538	70-75

Appukuttan (1987) has stated that oysters measuring 50-54 mm have grown by 15 mm reaching a size range of 65-69 mm within a period of 10 months time. He has observed two spawning seasons at Vizhinjam, one during March-June and the other in November-December. He has also observed a growth rate of 15 mm for oyster spat measuring 10-14 mm during the first month, and for spat measuring 25-29 mm a growth rate of 5 mm in the second month and states that the younger oysters exhibit faster growth rate which slows down as the oysters grow. In the present study spat measuring 25-30 mm have grown to 30-35 mm in 34 days time (Fig. 1 A3, A4). Similarly spat measuring 50-55 mm on 3-4-1988 have attained a size of 60-70 mm on 6th December 1988 within a period of about 8 months thereby showing a slightly faster rate of growth than what has been observed in India by Appukuttan.

Malpas (1933) working on the pearl oysters from Sri Lanka has used weight curve as a reliable index of age, as it was impossible to separate each generation of oysters from the natural bed, as there was considerable overlapping with successive spawning periods. Devanesan and Chidambaram (1956) have stated that the oysters grow to a height of about 36 mm in six months, 35-45 mm at the end of one year, 50-55 mm at the end of second year, 55-60 mm at the end of third year, 60-65 mm at the end of fourth year and 65-70 mm at the end of fifth year. The results obtained in Bahrain waters, show a much faster growth rate.

In Japanese oyster *Pinctada martensii*, Kafuku and Ikenow (1983) have mentioned that the spat grows to 5 to 10 mm size in about 3 weeks, 13 mm size in 45 days and 18-19 mm size in 60 days period. They have also stated that the oysters attain a size of 45 mm in one year. Kobayashi as quoted by Cahn (1949) has stated that the spat grows to 17 mm in 3 months, 31 mm by 6 months, 45 mm by one year and 70 mm by 3 years.

Nayar *et al.* (1978) in their experimental studies of the spat settlement and collection

of pearl oyster spat from Tuticorin, India, have stated that the oysters measuring 20 mm in size in February 1974 have grown to 55 mm group by October 1974 thereby registering a growth of 35 mm within a period of 8 months. In the present study it is seen that the spat measuring 15-25 mm on 21st December 1987 (Fig. 1 A2) have grown to a size range of 45-55 mm by 20th Ocotber 1988 within a period of about 10 months time which appears to be a slightly slower rate than what has been observed at Tuticorin.

Read (1966) stated that the pearl oyster *Pinctada margaritifera* breeds in the summer of second year. He mentioned that there is no trace of a gonad during the winter, but development begins by about March and continues until June. Eggs and sperm are discharged in the water at intervals until September, when the gonads become empty. He also stated that the well defined spawning season seem to be confined to that location in the Red Sea and attributed it to the influence of temperature which is about 24°C in March, rising to 32°C by June. The same author says that the species breeds intermittently throughout the year in North Australia when the temperature varies from 26°C to 31°C which does not seem to be very much different from Dongonab Bay in Red Sea. He has also stated that the spwning of the pearl oysters does not coincide with that of any other common organism which attaches to the spat collectors thereby eliminating the chances of settlement of the undesired species. His observation are useful for us here for intensifying the spat collection work and for carrying out various aspects of pearl oyster research programme.

Almatar *et al.* (1983) have studied the size composition of the oysters collected from the market and have stated that the growth rate of oysters is high during the first 12-18 months after settlement. They have also observed spawning activity cotinuing during the entire period of their observations, May-September.

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