Biology of Balanus Amphitrite Communis (Darwin) in the Cochin Harbour Waters

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[Seasonal variations in the incidence on fresh surfaces, breeding season, rate of growth and mortality of *Balanus amphitrite communis* was studied for a period of twelve months in the Cochin Harbour waters, situated 76° 14'E and 90° 57'N, and subjected to annual seasonal changes in salinity.]

Introduction

Among the organisms which foul the submerged surfaces of moving crafts like ocean going vessels, ships and tankers and the stationary harbour installations, barnacles are the most persistent. They are insulated against adverse environmental conditions by their shelly covering. *Balanus amphitrite communis,* which enjoys a circumtropical distribution largely because of its ability to tolerate wide variations of salinity, is the most dominant fouling component in the Cochin-harbour, located 76° 14′ E and 90° 57′ N.

Considerable work has been done on the biology of temperate and subtropical operculate barnacles (Barnes *et al* 1950, 1954, Crisp 1954, 1960, Moore 1934, 1935a, 1935b, Pyefinch 1948, Allen *et al* 1950, Atwood *et al* 1924). Investigations on the biology of barnacles of the Indian region are mainly confined to the harbours of Madras, Vizag and Bombay where near marine conditions persist throughout the year. (Paul 1942, Daniel 1954, Ganapathi *et al* 1958). In the Cochin-harbour, Erlanson (1936) has made only a passing reference to the existence of a rich barnacle community in the fouling complex. The present is therefore an attempt to provide experimental data on the seasonal variations in the intensity of occurrence on fresh surfaces, breeding, rate of growth, and mortality of *B. a. communis* in the Cochin-harbour, where the waters are subject to annual seasonal variations in salinity.

Experimental Procedure

Test blocks 12″ × 2″ × 2″, of *Mangifera indica* were exposed at two stations, one near the barmouth and the other further interior, which will hereafter be referred to as station A, and station B, respectively.

Hydrographic study for the period 1954 — 58 has shown that there is not much variation between different locations within the harbour. Therefore the test blocks were exposed at 2 localities only for replication sake. At each station thirteen test pieces, numbered 0 to 12 were exposed, the pieces being fixed to an iron frame suspended horizontally one foot below low water level. The piece marked 0 formed unit of a short term series and the others that of a long term series of blocks. The experiment was started in August 1959. At the end of the month, the pieces marked 0 and 1 were removed for observation substituting another piece marked 0. At the end of the next month the pieces marked 0, and 2 were removed, and thus the observations were carried out for the twelve consecutive months. The short term series of panels provided data about fresh attachment of the barnacles during each of the twelve successive months, and the others an index of the barnacle population for progressive durations.

The change that takes place in the intensity of occurrence of an organism during different periods can be indicated either by numerical counts of the organism or by the weight of the whole animals during the periods. In the present case, the latter method was adopted because after 30 days' exposure the test pieces were innumerable. The barnacles were scraped off separately from each panel and weighed after drying in folds of filter paper.

For growth studies of barnacles, the diameter of the basis along the rostro-carinal axis is usually taken into account. But Moore (1934) has shown that to study the growth rate of barnacles especially when the animal continuously changes its conicity throughout life, calculations of volume is necessary to cope with the variations of shape as between individuals and to afford a measure which unlike length increases more or less in a simple ratio with age. Therefore after determining the weight of barnacles on each test panel a random sample of 20 individuals was selected from each sample for calculating the average volume of an individual and the range of volume of the whole sample. Where the volume is referred to here, it is the volume of cone with the height equal to the height of the apex of the shell, and diameter equal to the average of the length and breadth of the base of attachment. Such an assumption no doubt does not take into account the truncation of the shell, but it gives a value sufficiently related to the external volume of the animal. In the tables the weight given for each month is the average for both the stations together, and the volume that of the sample from station B.

Simultaneous with the removal of thetest pieces a sample of nearly fifty barnacles was collected from nearby under-water structures to study the stage of maturity of gonads applying the method suggested by Pyefinch (1948). Throughout the period of investigation weekly collections of plankton were made by surface hauls of thirty minutes duration with a net made of bolting silk. The number of nauplii was counted and the intensity for a month was determined by taking the average of the four weekly counts.

Along with the collection of plankton, the temperature and salinity of the surface water were also determined. These values given in the tables represent the average of the values from both the stations together.

Results

Seasonal variations in the incidence of *balanus* on fresh surfaces. Table I gives the weight of *Balanus* that had occurred on the short term panels during successive months, intensity of other foulers and borers for each month and the hydrographic data.

In the locality under reference there are three distinct seasons, two rainy and the other nonrainy. From May to August the heavy S. W. monsoon rains floods the rivers and the flushing out of the fresh water brings down the salinity in the harbour area to the low level of 00.30 parts per thousand by the end of July, and this low saline condition persists only with slight variation till the end of August. From September to December is the N. E. monsoon season. During this period the rains are only moderate and rivers are not usually flooded. Nevertheless there is steady flow of fresh water into the harbour area, making the water in the region essentially brackish, with salinities ranging from 11.2 to 26.7 parts per thousand. From January to April, the season is dry with practically no rain at all. During this season the harbour area is under the full impact of the tides and the salinity of the water approaches that of the adjoining sea.

Scrutiny of Table I will show that there is a uniformly high rate of occurrence of *Balanus* from September to December, when the water is essentially brackish, and a much diminished but more or less uniform rate of incidence during the rest of the year, except June, when there was no settlement at all. This shows that in the Cochin-harbour, *B. a. communis* is capable of infesting fresh surfaces almost throughout the year, with a pronounced rate of infestation during September to December.

Breeding season. Three lines of investigation were pursued in determining the breeding season. They were (1) studying the state of maturity of the ova within the body of the pile population, (2) determiningthe comparative abundance of nauplii in the plankton and (3) verifying the seasons of fresh infestation.

Fig. 1. shows the proportion of individuals with different stages of the ova represented as percentage of the total number of individuals collected from old piles. From the same it will be seen that the population shows the presence of ova in the first stage of development in August. During September and October the ova are in a more advanced state of maturity (stages 2 and 3) and by November become ready to hatch. During the succeeding four months (December - March) the proportion of individuals with mature ova steadily increased and in April, 80% of the collection were dead and the rest 20% contained mature ova and in May again 80% of the individuals were dead and the rest immature. During June, and July the entire population was formed of immature individuals. To sum up, fully developed ova are seen from November to April, indicating a definite breeding season, among the population of *Balanus* within the harbour.

Table II shows the presence of nauplii throughout the year, with a pronounced increase in their number from November to May. It will be noted that this period when there is an increase in the number of nauplii almost coincides with the breeding season of the population within the harbour.

It will also be recalled (Table 1) that except in the month of June settlement on fresh surfaces occurred throughout the year. It is therefore evident that *Balanus amphitrite communis* is capable of breeding throughout the year, but within the population of the harbour waters, the breeding is restricted to the season November to April.

TABLE I. Details of Attachment on Short Term

	August	September	October	November	December
Salinity 0/00	0.65	11.20	16.5	17.9	26.7
Temperature ° C.	28.5	28.5	29	28	28.5
Weight of Balanus in grams	5.60	16.70	16.55	17.90	16.00
Other organisms					
Coelenterata	nil	H. (r)	H. (r)	H. (r)	H. (r)
	nil	nil	nil	nil	nil
Nematoda	nil	f.worms 5	f.worms 10	nil	f.worms 3
Polychaeta	f. l. p. 60	f. l. p. 94	f. l. p. 20	nil	f. l. p. 22
	nil	nil	nil	nil	nil
Crustacea	nil	nil	nil	nil	S. terebrans. 3
	nil	other isopods. 2	other isopods. 6	other isopods. 46	nil
	nil	amphipods 2	amphipods 10	amphipods 8	amphipods 20
	nil	brachyura 5	brachyura 3	brachyura 2	nil
Mollusca	nil	nil	modiolus	nil	nil
	nil	nil	nil	nil	nil
	nil	nil	nil	nil	nil
	nil	nil	nil	nil	nil
	nil	gastropods. 18	nil	nil	nil

H — Hydroids, (r)—rare, (c)—common, f.—worms—Flat worms

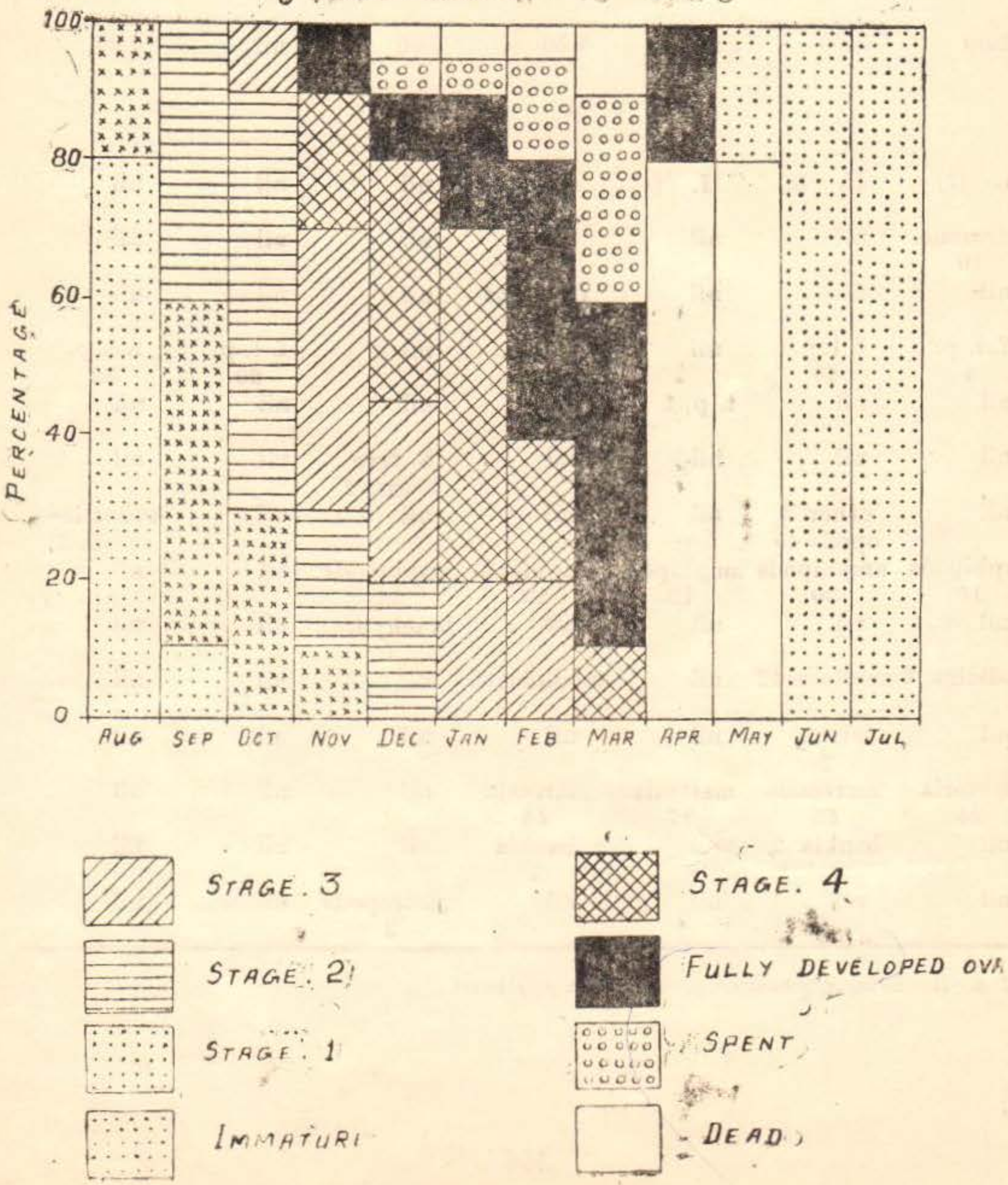
Series of Panels After Each 30 Days (1959—1960)

January	February	March	April	May	June	July
31.7	32.85	34	34.15	17.5	2.15	0.3
28.5	28	29	29	29	28.2	29
2.00	3.00	2.00	8.50	5.00	nil	5.00
H. (r)	H. (c)	H. (c)	H. (c)	nil	nil	nil
anemone. 10	nil	nil	nil	nil	nil	nil
nil	nil	nil	f. worms 4	nil	nil	nil
f. l. p. 4	f. l. p. 40	nil	f. l. p. 40	nil	f. l. p. 20	f. l. p. 32
nil	nil	t. p. 1	nil	nil	nil	nil
nil	nil	nil	nil	S. tere brans. 2	nil	nil
nil	other is opods 45	nil	nil	nil	nil	other is- opods 3
amphipods 10	amphipods 30	amphipods 12	amphipods 20	amphipods 32	nil	nil
nil	nil	nil	nil	brachyura. 1	nil	nil
modiolus 6	modiolus 12	nil	modiolus 66	nil	nil	nil
nil	ostrea 2	nil	nil	nil	nil	nil
martesia. 24	martesia. 53	martesia. 27	martesia 44	nil	nil	nil
nil	bankia. 2	nil	bankia 1	nil	nil	nil
nil	nil	nil	nil	gastropods 2	nil	nil

f. l. p.—free living polychaets, t, p.—tubiculous polychaets.

FIG. 1

SHOWING THE PERCENTAGE OF INDIVIDUALS WITH DIFFERENT STAGES OF DEVELOPMENT OF THE OVA IN THE COLLECTIONS FROM OLD PILES



Mortality. Table III gives the total weight of *Balanus* found on the long term series of the test blocks, and the average volume of the sample during successive months of the experiment.

From August to December, a steady increase in weight and a corresponding increase in average volume are noticed. This increase in average volume is maintained till May. But in spite of the increase in volume, starting from January and lasting up to May, the total weight shows a decline. The obvious inference from this is that even though the shells of the individuals included in the collection occupied larger volumes, many of the individuals collected from January to May were dead with their soft parts lacking.

The decline in the total weight is reversed and the total weight shows an increase in June. It will be noted that in June, the average volume is lesser than that in the previous month. From the range of volume also, it will be seen that the June population was formed of small individuals. Therefore the increase in weight in June, in spite of the comparatively small size of the individuals suggest that the entire population consisted of live ones with their soft parts intact. The same trend continued in July also. From these observations it is evident that there was considerable mortality among the population on the long term series of panels during January to May.

This observation on the mortality from January to May is also confirmed by field notes recorded at the time of collection every month. For the first time during the present study it was noticed in January that most of the population on the long term panels were dead and that bivalves *Modiolus.* sp. have settled within their empty shells. This state of affairs was noticed till the end of May.

The mortality of the barnacle population from January to May is also confirmed by the composition of the samples from other submerged structures (Fig. 1).

Comparison of the range of volume for May and June (Table III) will show that the largest individual collected in June was much smaller than that in May. This observation together with the mortality noticed during January to May indicate that mortality has affected mainly the larger individuals.

Seasonal variations in the rate of growth. Fig. 2. is the histogram based on the volume of the individuals from the short term series of the panels, in other words, the growth of the population after every thirty days. If the unusually rapid growth in October is treated as an exception the lowest value is that for July and August, those for September, November and December higher than the previous two months, and those from January to April highest. If this rate of growth is correlated with the salinity (Table I) it becomes abundantly clear that the growth rate is directly correlated to the salinity of the harbour area.

Discussion

It has to be admitted that the present investigation was confined only to a single year. Any firm conclusions require observations for a prolonged period. Therefore conclusions that are drawn here have to be considered as tentative.

TABLE II. **The Intensity of Nauplii in the Plankton During Each Month. (1959—1960)**

	Aug.	S.	O.	N.	D.	J.	F.	M.	A.	M.	J.	July.
No. of larvae in the whole sample.	220	450	425	1825	2365	2250	2000	2820	3225	1850	280	250
Salinity parts per thousand	0.65	11.20	16.5	17.9	26.7	31.7	32.85	34	34.15	17.5	2.15	0.3

TABLE III. **The Details of Balanus Population on the Long-Term Series of Panels After Each 30 Days (1959—1960.)**

	Total weight of Balanus in gms.	Average volume of an individual in the collection in mm^3	Range of volume of the collection in mm^3
August	6	14.00	13.20
September	17.5	26.00	12.6 to 33.5
October	29.4	104.00	85 to 158
November	57.40	201.00	131 to 301.7
December	133.00	213.00	170 to 300.8
January	56.00	231.00	188 to 308
February	40.00	250.00	190 to 301.8
March	22.00	305.00	170 to 309.8
April	19.00	335.00	190 to 334.00
May	10.00	416.00	38 to 354.00
June	13.00	183.00	56 to 184.00
July	16.00	196.00	86 to 189.00

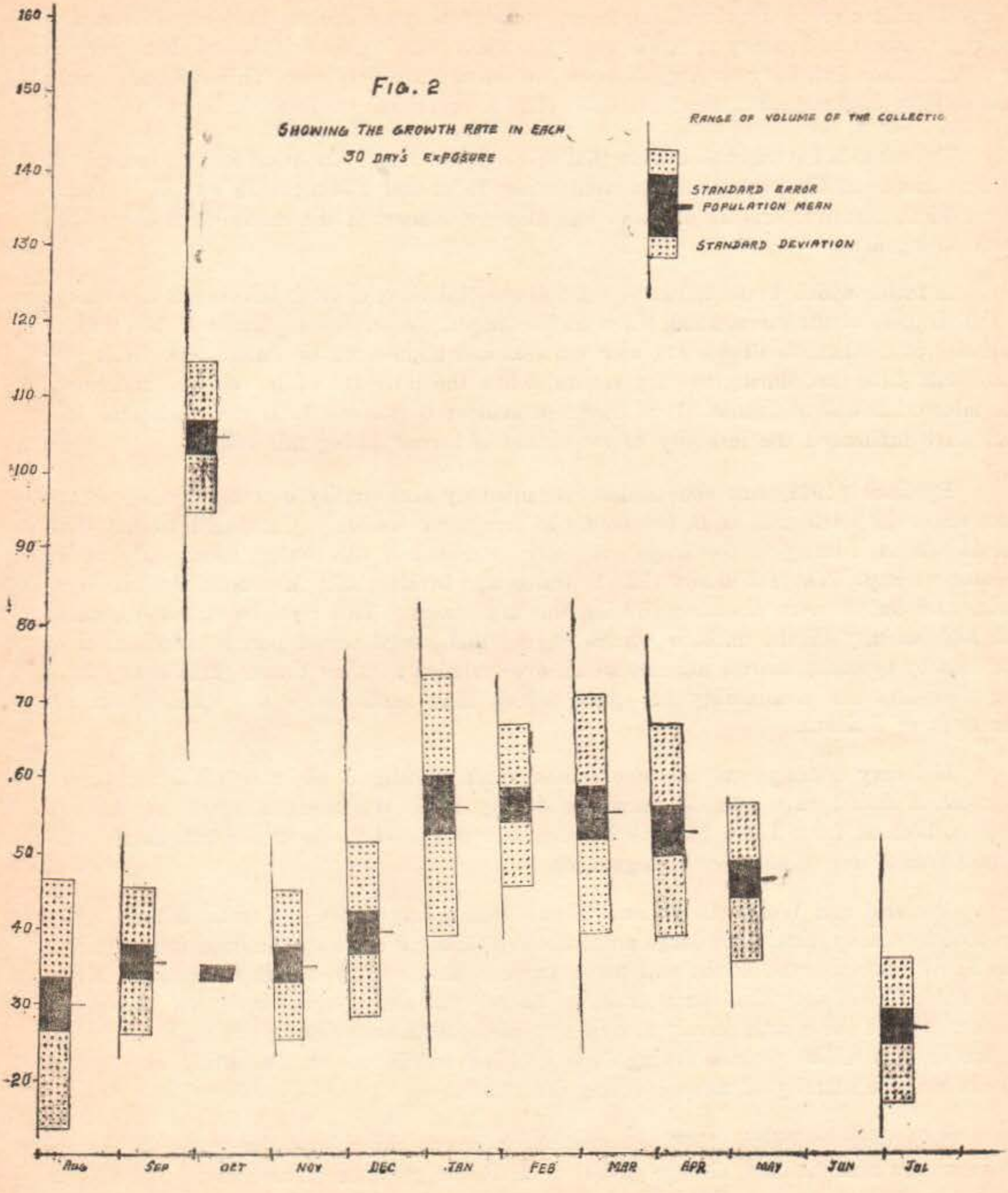


FIG. 2

SHOWING THE GROWTH RATE IN EACH 30 DAY'S EXPOSURE

It was seen that the maximum intensity of barnacles on fresh surface occurs during the N. E. monsoon season i.e., September to December when the water is essentially brackish. It will also be recalled that their intensity is more or less uniform both during the dry season i.e., January to April when the water was highly saltish and during S. W. monsoon season i.e., May to August when the salinity was very low. This evidently shows that salinity does not affect the infestation of*B. a. communis* on fresh surfaces.

From Table I it will also be seen that there is not much variation in temperature of water throughout the year, the maximum being 29°c, and minimum 28°c : It is therefore evident that temperature of water has also not influenced the intensity of occurrence on fresh surfaces.

A factor which would normally influence the intensity of fresh infestation of *Balanus* is the richness of the surrounding water in the nauplii larvae. A comparison of the seasonal intensity of the nauplii (Table II) with the seasonal abundance of *Balanus* on fresh surfaces will show that during the dry season, when the intensity of larvae was maximum, the infestation was minimum. It is therefore evident that some local environmental factors have influenced the intensity of settlement of larvae during this season.

Pyefinch (1948) has shown that the intensity and quality of other fouling organisms affect the settlement of *B. balanoides* in temperate waters. Compared to the temperate waters, fouling in the tropics is more intense and the fouling community shows greater variety. Table I shows that hydroids and bivalves like *Modiolus, Bankia, Martesia*, and *Ostrea* were abundant during the dry season. This is to be expected because the high salinity of the harbour waters during this period would permit colonisation of the area by typically marine animals which are excluded at other times. This heavy fouling decreases the availability of space, which may result in a low intensity of attachment of *Balanus*.

If heavy fouling was the sole factor which influenced the rate of settlement of *Balanus*, it should have been the maximum during the S. W. monsoon season i.e., May to August, because from Table I it will be seen that during this season the test panels were almost free of any other types of organisms.

Pomerat and Weiss (1946) have shown that greasy and slimy surfaces are usually avoided by the cyprids. The large amount of silt brought down by the flood waters during the S. W. monsoon no doubt will make the test blocks slimy during the season. Moreover Table II will show that the intensity of nauplii was also comparatively low during this season. Hence the comparatively low rate ot fresh settlement during the S. E. monsoon season and its initial absence during June may be attributed to the silting of the test blocks and the scarcity of nauplii during the season.

According to Pillai (1958) *B. amphitrite* breeds throughout the year. In the inshore waters near Calicut, George (1953) noticed the presence of nauplii throughout the year. On the East coast at Madras, Daniel (1954) and at Vizag, Ganapathi *et al* (1958) founded that *B. a. communis* is capable of breeding throughout the year.

Thus all the evidence available show that the species is a continuous breeder in the open sea. During the present study it was noticed that even though in the population of *Balanus* within the harbour, breeding is restricted to a particular period, nauplii were present in the plankton throughout the year. In the light of earlier evidence about the continuity of breeding of the species it is probable that the nauplii that occur in the harbour plankton outside the season of breeding of the harbour population are those brought down into the area from the adjacent sea.

That the breeding in a limited population of the species as that of the harbour is restricted to a definite season is also confirmed by the observations of George (1958) who was able to collect nauplii at Narackal only from December to June. Narackal is far away from the barmouth and the effect of high tide is negligible, during the season i.e., January to April. Panikkar and Aiyar (1939) have also observed that *B. amphitrite* is able to reproduce in brackish water only during a few months of their annual existence.

It will be recalled that in Madras and Vizag where breeding in *B. a. communis* has been noticed throughout the year where near marine conditions persist throughout the year. The absence of breeding activity among the *Balanus* population in the Cochin-Harbour during a part of the year may be attributed to the wide variations of salinity in the area. From November to April when there is breeding, the salinity is relatively high, and May to October when no breeding is noticed salinity is low. It is possible that the low salinity inhibits the breeding potential of the harbour population and thus restricts its breeding activity from November to April, when the salinity is relatively high.

The appearance of an apparent breeding and off season for *Balanus* population in the harbour may also to some extent be due to the following. From January to May as was already seen there is considerable mortality among mature individuals, and by May the living population is mainly formed of immature individuals. Paul (1942) has observed that in the Madras Harbour *B. amphitrite* attains sexual maturity in 16 days. In Madras the lowest salinity recorded was 30%. But in the present locality the immature individuals that remain after the mortality period have to face very low salinity. During the three months that ensues i.e., June to August the salinity does not exceed 2.15 parts per thousand (Table 2). During September and October also the salinity is very low as 11.2 parts and 17.9 parts per thousand respectively. Correlation of Fig. 2 with Table I has shown that the rate of growth is influenced by salinity and it was also shown that low salinity will inhibit the breeding potential. It is therefore possible that the immature *Balanus* which remains in the Cochin-harbour after the mortality period may have a prolonged pre-maturity growth period unlike in the Madras-harbour. Once they mature by about November breeding becomes continuous till next January when mortality again sets in. Thus the absence of mature individuals during a part of the year within the harbour area gives a false picture of the overall breeding activity of the sub-species.

It is difficult to account for the annual mortality of the fully grown up individuals. It is interesting that the mortality occurs during January to May, when the growth rate was maximum. But it will be noted that the growth rate was recorded only in juveniles whereas the mortality was noticed in fully grown up individuals. Runstorm (1926) found that *B. balanoides* usually liberates larvae at the end of the third year and later die. It is well known that in the colder waters the prematurity growth period is long. In the tropics, because of the uniformly high temperature, prematurity growth period is short and animals reach maturity comparatively earlier. The life span of the individuals also varies accordingly. Obviously therefore, it may be that *B. amphitrite* grows to maturity, liberates the larvae and die during the course of a year. Whether the death occurs after the liberation of a single brood of larvae or after successive liberations could not be ascertained.

Summary

Observation for 12 months within the Cochin-harbour with test blocks of 30 days' exposure showed that *B. amphitrite communis* is capable of infecting fresh surfaces throughout the year, with a peak period of settlement during N. E. monsoon season i.e., September to December. The comparatively low rate of infestation during the dry season i.e., January to April, in spite of the maximum intensity of nauplii in the plankton is attributed to the presence of other sedentary organisms, among which *Martesia* plays a prominent part. The low rate of infestation during the S. W. monsoon season i.e., May to August is attributed to the heavy silting and scarcity of nauplii during the season.

Nauplii were collected from the harbour throughout the year, and fresh attachment also took place throughout showing the continuity of breeding of the sub-species. But examination of monthly samples from pile population showed that the population within the harbour breeds only from November to April.

Comparison of the weight and volume of samples from a long term series of blocks with progressive durations of exposure showed mortality among mature individuals from January to May. This mortality is confirmed by observations on the population from nearby submerged structures also.

The breeding of the harbour population to a limited period is suggested to be due to (1) low salinity during the off season and (2) the annual mortality of the mature individuals from January to May.

Observations on the growth of individuals during every 30 days showed that the growth rate is directly correlated to the salinity variations in the area.

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