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STUDIES ON SOME ASPECTS OF BIOLOGY OF THE WEDGE-CLAM, *DONAX FABA* GMELIN FROM MANDAPAM COAST IN THE GULF OF MANNAR*

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RESEARCH work on the biology of edible molluscan shellfish was started comparatively recently in India and there have been considerable preliminary and some detailed investigations on various species of local importance and the results obtained are of some value. Some of the notable contributions are : on *Paphia undulata* (Winckworth, 1931), on *Mytilus viridis* (Paul, 1942), on *Crassostrea madrasensis* (Paul, 1942 ; Rao, 1951, 1956 ; Rao and Nayar (1956), on *Mytilus* sp. (Jones, 1950), on *Katelysia opima* (Rao, 1952), on *Meretrix casta* (Abraham, 1953 ; Durve, 1963), on *Pinctada* sp. (Gokhale *et al.*, 1954), on *Sepioteuthis arctipinnis* (Rao, 1954), on *Donax cuneatus* (Nayar, 1955), on *Crassostrea gryphoides* (Durve and Bal, 1961, 1962 ; Durve, 1964a and 1965) and on *Solen kempi* (Rao *et al.*, 1962). These studies have broadly elucidated some aspects of biology of these molluscs such as growth, feeding and spawning.

The wedge-clam, *Donax faba* Gmelin is one of the few clams collected for culinary purposes by the coastal population, especially the fishermen community, around Mandapam on the south-east coast of India. Investigations on the biology of this clam were undertaken at the Central Marine Fisheries Research Institute and the results based on two years' observations are given in the following account.

The material for this study was regularly obtained from the sandy beach which lies between the Institute and the coastal village Vedalai, in the Gulf of Mannar, on the south-east coast of India (Long. 79° 8'E., Lat. 9° 15' N.). The methods employed for the different aspects of this study are discussed under the respective sections.

THE ENVIRONMENT

The sandy beaches around Mandapam are replete with one bivalve species or the other, by far the commonest among them being the species of *Donax*. In the area from where *Donax faba* has been collected other species that occur along with it are *D. cuneatus*, *D. incarnatus*, *D. spinosus* and *D. aperittus*. While the first two species are found in fairly good numbers the other two are very rare.

The beach in this region is narrow, very slightly sloping, with coarse sand grains near the low water mark, medium sized ones at the middle and fine grains at the high water mark. Seed clams along with a few larger ones are abundant in the latter region and the larger ones dominate the mid water mark. At the low water mark,

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characterised by the presence of dead shells and coarse sand grains, only large clams occur as the nature of the bottom is not conducive for young or seed clams to thrive. Though this is the general distribution pattern, due to the wave action during high tide, sometimes the young and the seed clams appear near the low water mark, but then, they probably work their way up to the fine sands. The clams have not been obtained from below low water mark.

Data on temperature and salinity of the nearshore waters at the area of collection of clams were obtained for the period August 1962—December 1963 and are presented in Fig. 1. The range of temperature and salinity during the period was from 26.5 to 30.5°C. and from 26.37 to 36.96‰ respectively. Taking an year's

FIG. 1. Monthly variations in the mean values of salinity and temperature in the inshore waters near the clam bed during the period August 1962-December 1963.

picture from January 1963 it is seen that the salinity and temperature are low to begin with and then show a steady increase. The values for salinity are on the increase until the maximum (35.62‰) is reached in October, except for a small decline in April. From October onwards the salinity drops down steeply and reaches the minimum (26.37‰) in December. But in the case of temperature the maximum value of 29.75°C. is reached in April and then there is a decrease to 27.75°C. in June. The temperature again begins to rise and reaches 28.5°C. in September and thereafter shows a decrease to 26.5°C. in December. The low values of temperature and salinity obtained during December and January are the direct result of precipitation in this region by the North-East Monsoon which causes from moderate to occasional heavy showers from October to January. Prasad (1957) considering the temperature conditions, classifies this area as ' homostenothermal ' because of its 'relative stability and almost uniform conditions' within a year and as 'monimothermal' as the temperature condition remains 'relatively constant from year to year.'

AGE AND GROWTH

Methods—Among the different methods that are in vogue for studying the growth of bivalves the length frequency method has been employed in determining the age and growth of *Donax faba*. Though there are found certain rings on the shell, they have not been considered here due to the difficulties in ascertaining their nature and origin. The initial experiments of marking the clams and releasing them in the beach did not yield fruitful results and hence discontinued. Random samples were collected from the clam bed every fortnight from July 1962 to June 1964 and the length of the clam was measured correct to 0.1 mm. with Vernier calipers. Length, here, is taken as the maximum distance from the anterior end to the posterior end of the shell. Not finding any appreciable difference in the length frequency distribution of the samples collected in the same month the fortnightly data were pooled monthwise and the percentage frequency of the size groups at 2.0 mm. interval was obtained for each month (Figs. 2 and 3).

Observations—From the study on the reproductive cycle of *Donax faba* which is described in the next section, it is evident that the breeding period is a prolonged one extending from early November to June. The adult population does not appear to spawn synchronously and hence within the spawning season a number of overlapping broods appear due to different individuals spawning at different times so that any distinct mode is absent in the length frequency distribution.

Seed clams having a modal range of 2.5 to 5.5 mm. occur in the samples of March to September 1963 and February to June 1964. Because of the appearance of fresh broods over a fairly long period there is enormous overlapping of the year classes. But a fairly prominent group (marked X in Figs. 2 and 3) starting with a modal length of 6.5 mm. in August 1962 records a steady growth, as can be seen from the shifting of modes, and attains 19.5 mm. in May, thereby indicating that during the 9 month period from August to May the clam has grown from 6.5 mm. to 19.5 mm. *i.e.*, 13 mm., at an average rate of about 1.4 mm. per month. As the growth rate is expected to be higher during the early period of life, the clams with the mode at 6.5 mm. in August may be considered to be not more than 3 months old. Therefore, assuming that this group is the result of a peak spawning by the parental stock in May 1962 and noting the subsequent growth up to 19.5 mm. in May 1963 it can be said that the clam completes one year of its life at modal size of 19.5 mm., giving an average growth rate of 1.6 mm. per month.

The same group, as can be seen from the figures, shows further growth in the succeeding months, and after reaching 22.5 mm. in September 1963 loses its identity. From this it may be seen that in the second year the clam has grown from 19.5 mm. in May to 22.5 mm. in September at a rate of about 0.75 mm. per month. After the group attains the size of 22.5 mm. the growth rate further slows down as may be seen from the stationary position of the mode at 22.5 mm. after September. In the absence of any large scale mortality or removal of clams over 22.5 mm. in size which could cause the stagnation of mode, it can be said that during the latter half of the second year the clam has an extremely slow growth rate and at the end of the second year it does not grow to more than 23.5 mm. in size. This can be seen from the presence of a distinct mode at 23.5 mm. in May 1964 which has remained so even from January 1964.

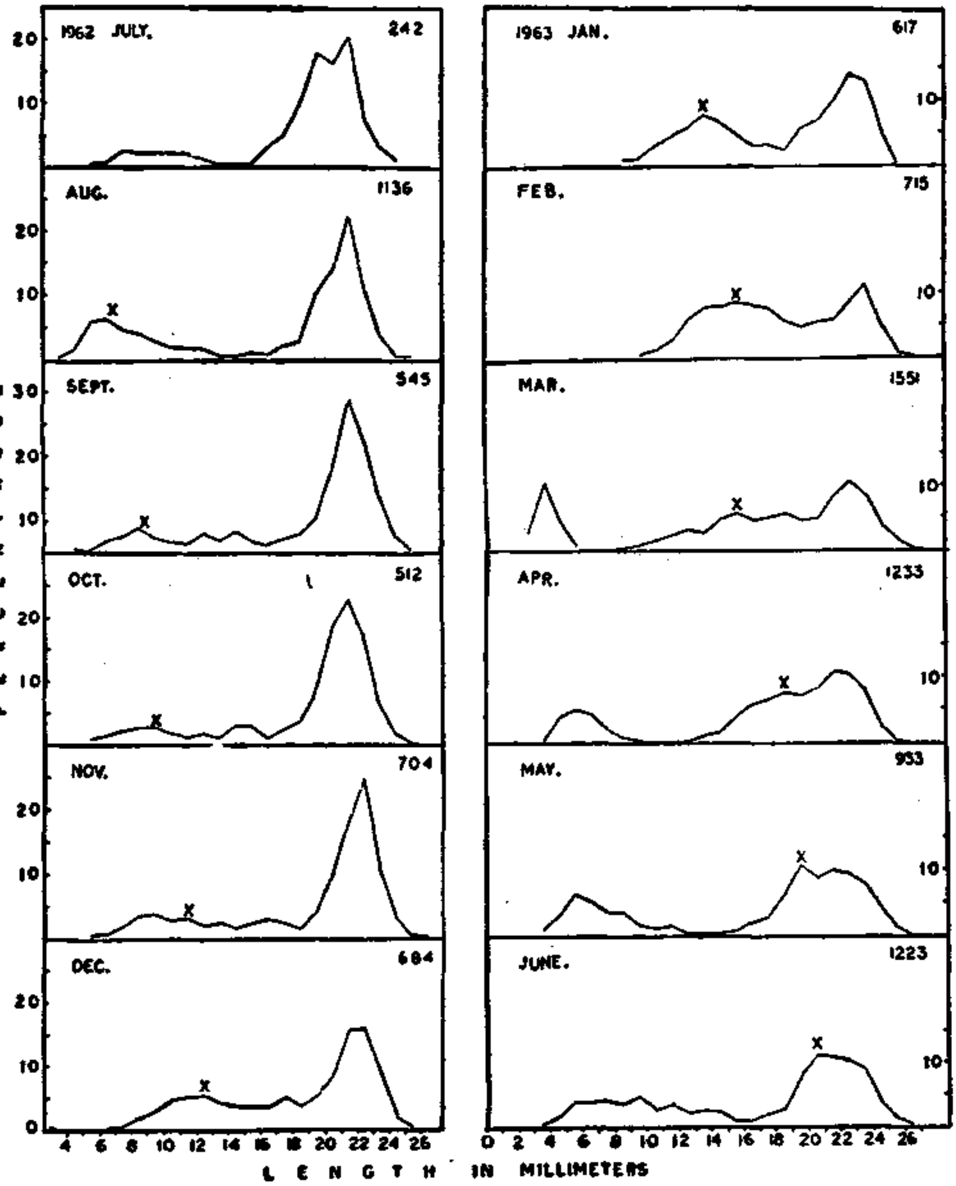

FIG. 2. Length frequency distribution of *Donax faba*. (The total number of clams is given at the top right corners.)

It is not possible to estimate by size frequency method the size of the clam at ages over two years. Noting that the maximum size encountered is 27.3 mm. it

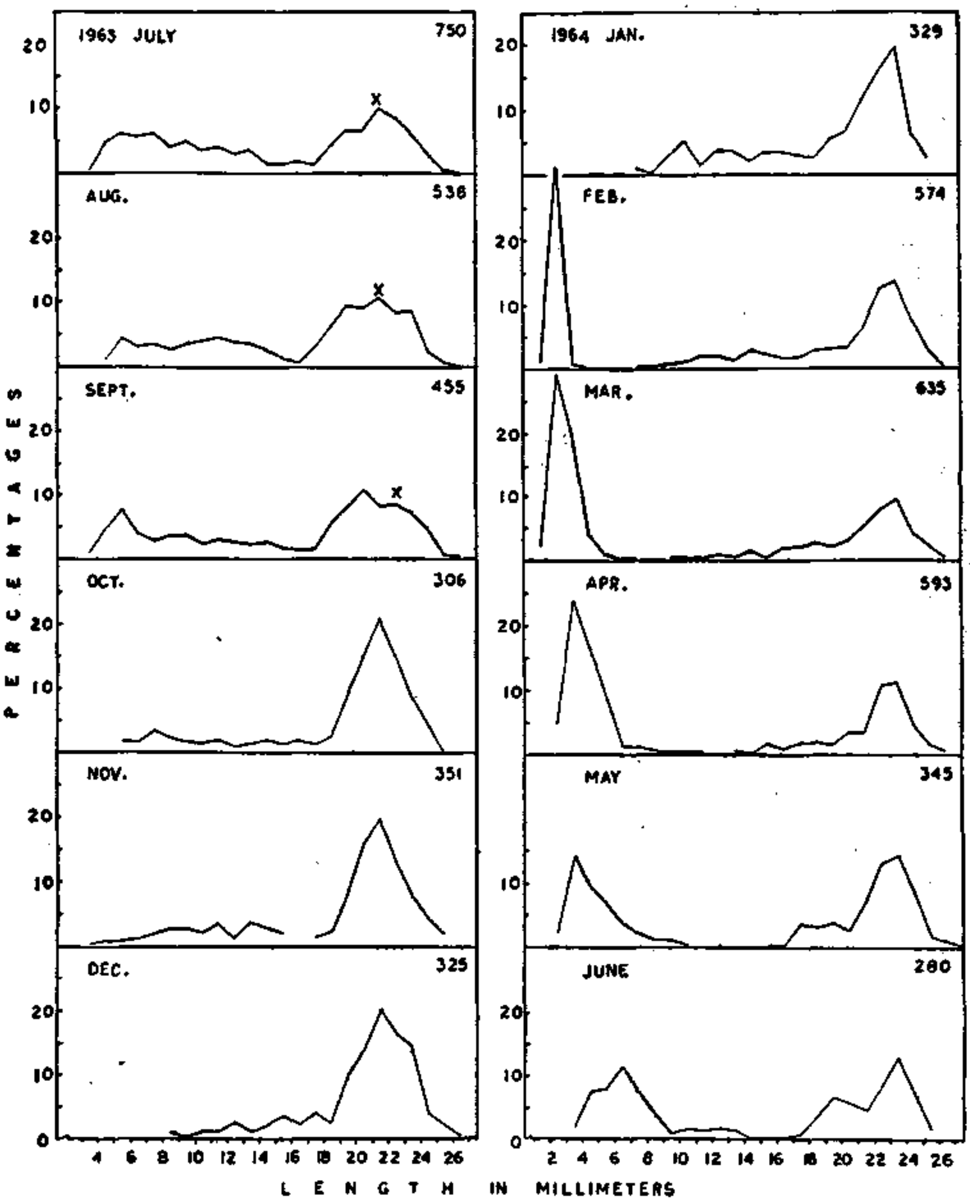

FIG. 3. Length frequency distribution of *Donax faba* (*Contd.*). (The total number of clams is given at the top right corners.)

is possible that the life span of *Donax faba* exceeds two years, even though the number of clams older than two years is very few, but may not survive the third year.

Discussion—Nayar (1955) has observed a maximum growth of 13-14 mm. in 11 months in the case of *Donax cuneatus*, a species that occurs in a similar environment. The present species has a higher growth rate at 1.6 mm. per month. Nayar (*loc. cit.*) describes the presence of growth rings indicating cessation of growth during November-December when the environmental conditions are unfavourable. From the present observations on *Donax faba* it is not possible to say if there are periods of no growth as found for *Donax cuneatus*. It can only be said that the rate of growth becomes slow during the second and subsequent year of life. Coe (1955) has found that the bean clam, *Donax gouldi* from the coast of Southern California attains the size of 12 mm. at the end of one year, 18 mm. at two years and 20 mm. at about the end of third year. The species seldom survives after the second year as at the end of spawning during that year most of the clams may perish. Compared to these findings the growth observed for *D. faba* is faster in the first and second years.

Growth of Body Characteristics in Relation to Size

In order to see how the body characteristics of *D. faba* grow in relation to length data on length, height, thickness and weight were collected. Height is the vertical distance from the umbo to the ventral margin of the shell and thickness is the lateral distance between the two valves measured on the outer surface.

Methods—For the study of length-height and length-thickness relationships clams ranging from 2.1 mm. (minimum size obtained during the collections) to 27.3 mm. (maximum size) were measured correct to 0.1 mm. For the length-weight relationship, in a month when clams of all sizes were available in the bed they were collected and left in sea water. When the clams were found to be filtering actively they were removed one by one and after drying the external moisture, the length and weight (correct to a milligram) were found out. The clams used for this study ranged from 2.8 to 26.5 mm. in length.

Observations—The relationships between length and height, and length and thickness are seen to be of linear type. The lines fitted by the least square method are represented by the equation $Y = -0.4244 + 0.6873\,X$ (Y denoting height and X length) and $Y' = -0.5869 + 0.3671\,X$ (Y′ denoting thickness and X length) respectively (Figs. 4 and 5). For the length-weight relationship the general formula $W = a\,L^{b}$ was fitted. Least square estimates of a and b were obtained from the data. The logarithmic formula obtained is $\text{Log } W = -3.9833 + 3.17304 \text{ Log } L$ and the general equation is $W = 0.0001040\,L^{3.17304}$ where L stands for length and W for weight (Fig. 6).

Reproductive Cycle

From the Indian waters though a fairly large number of molluscan species have so far been covered detailed investigations on the reproductive cycle have been carried out with respect to a few species only, such as *Crassostrea madrasensis* (Rao, 1951, 1953, 1956), *C. gryphoides* (Durve, 1965), *Meretrix casta* (Durve, 1964b). Some of the species on which only a few observations have been made are *Crassostrea cucullata* (Awati and Rai, 1931), *Mytilus viridis* (Paul, 1942), *Mytilus* sp. (Jones, 1950), *Donax cuneatus* (Nayar, 1955), *Katelysia opima* (Rao, 1952) and *Solen kempi*

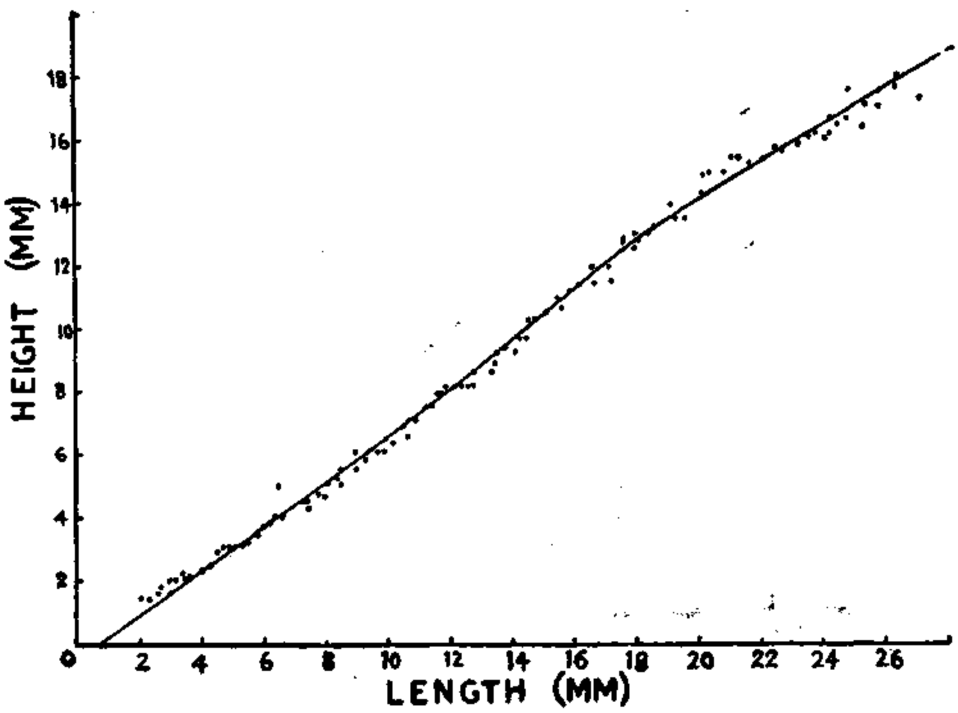

FIG. 4. Length-height relationship in *Donax faba*.

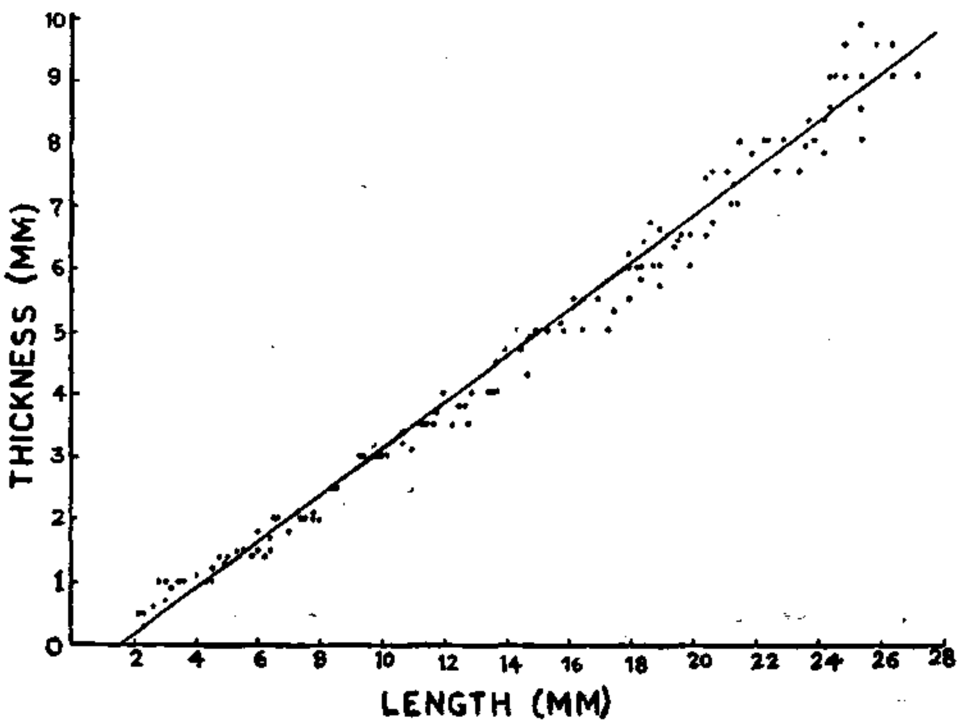

FIG. 5. Length-thickness relationship in *Donax faba*.

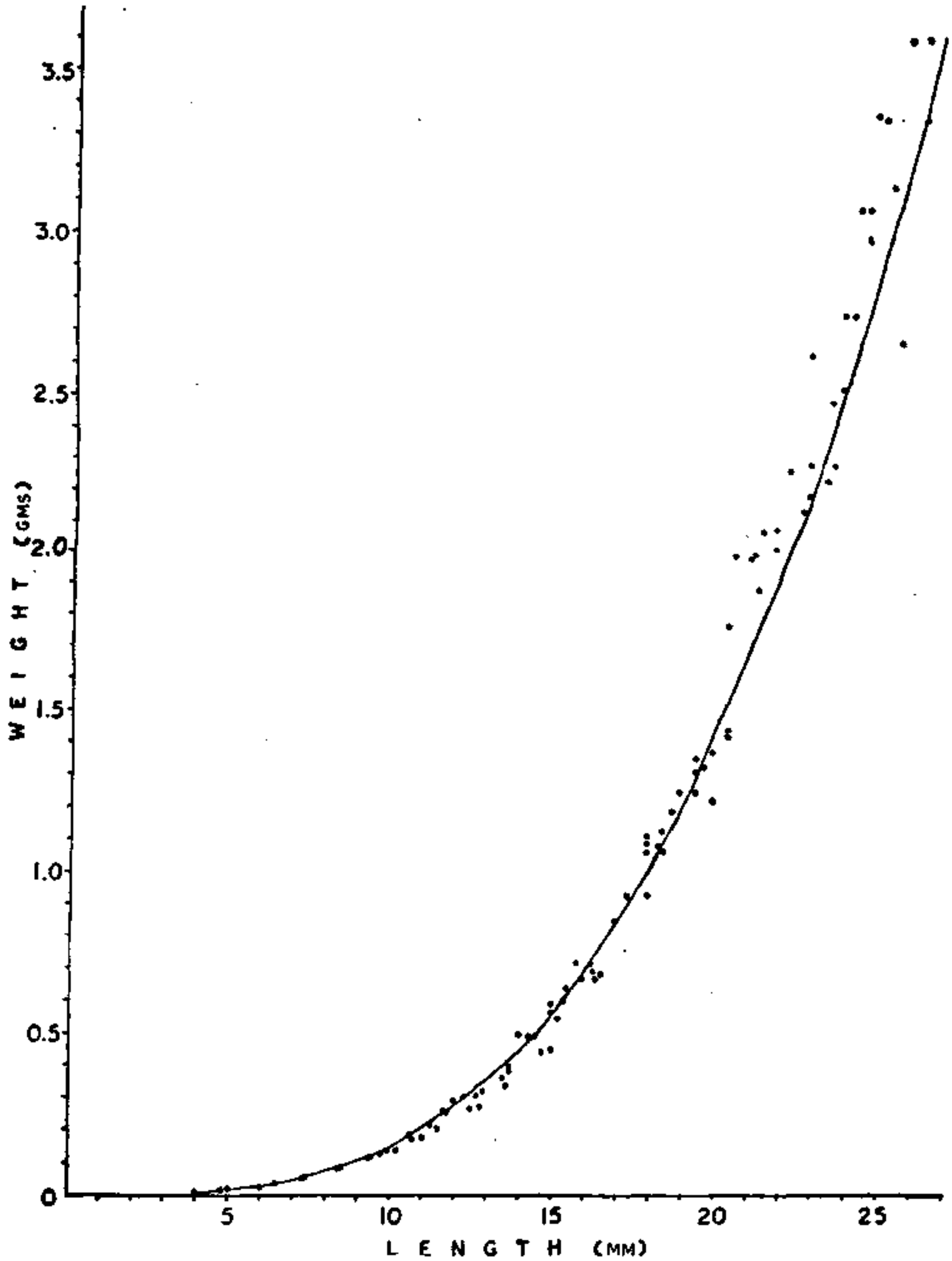

FIG. 6. Length-weight relationship in *Donax faba*.

(Rao *et al.*, 1962). In the present study an attempt has been made to trace the development of gonad, maturation and spawning in *Donax faba* and to follow the histological changes that take place due to these processes.

Methods—During the period August 1962 to December 1963 weekly samples of at least 50 individuals were examined fresh and the macrostructure of the gonad, sex of the individual, abundance of gametes and the general condition were ascertained aided by microscopical examination of the smear. Tissues of clams measuring from 6-7 mm. onwards in length representing broadly the various phases of the gonad as present in the sample, were fixed in Bouin's fluid. Sections of the tissues were prepared and stained with Ehrlich's haematoxylin and eosin. In all a total of 2495 clams were studied by the smear technique and 185 clams by histological preparations. The reproductive cycle has been determined by examining the results obtained from both the methods. In order to ascertain the size at which the clams attain sexual maturity a series of young clams ranging from 7 mm. onwards were collected in the months of active gametogenesis and were examined in detail by the methods above stated.

Observations—In the following analysis, the reproductive cycle of *D. faba* is treated monthwise as considerable changes have been observed from month to month. In fixing the phases of the cycle the works of Shaw (1964) and Ropes and Stickney (1965) have been followed. While the ' active phase ' ' ripe phase ' and ' partially spawned phase ' have been followed here as such, the ' spent phase ' and ' inactive phase ' have been treated together under ' spent and resting phase ' as the differences observed were few. The monthwise percentages of clams in the various phases for the period January-December 1963 are given in Fig. 7. Since August is the month when a great majority of the clams are in the ' spent and resting phase '

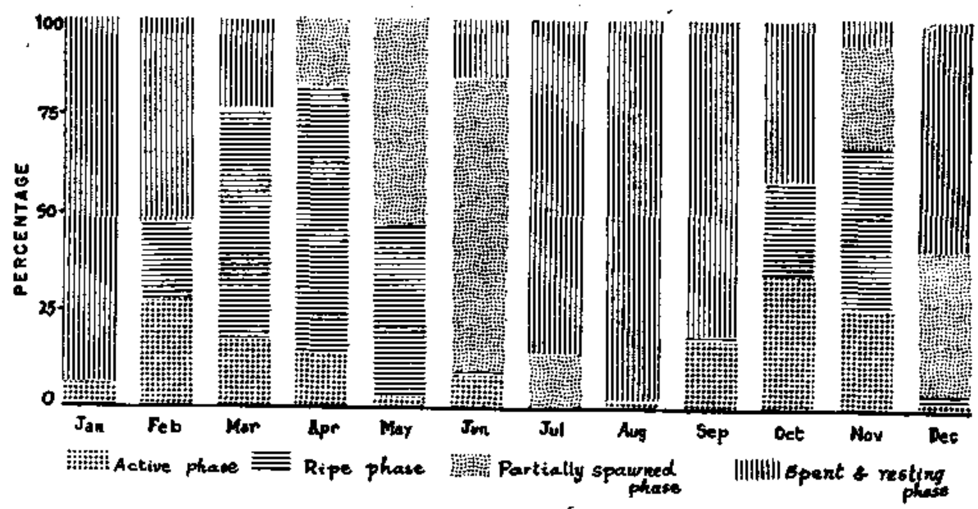

FIG. 7. Monthwise percentage distribution of *Donax faba* in different phases of the reproductive cycle during the year 1963.

which is convenient to begin with, the reproductive cycle is treated from this month of the year 1962.

August: The gonads, in general, are in the resting phase. A few of them contain shrunken follicles with residual ova in the lumen or with relict sperms to be cytolysed. In some cases phagocytic cells surround the degenerating follicles and in a few they have invaded the unspawned gametes. In a very few clams the gonads are found in the active phase. Small follicles are being proliferated from the germinal epithelium. The lumen is formed in some cases and the follicular wall is found to contain 3 to 4 layers of deeply staining uniformly sized primary spermatogonia or oogonia. The follicles are found only here and there and are not anastomosing. The connective tissue occupies the major portion of the gonad.

September: The gametogenic activity initiated during the previous month becomes vigorous now and the percentage of clams in the active phase increases (Pl. I, fig. 1). The gonads can easily be distinguished from other parts of the body. The branching nature of the germinal epithelium becomes distinct and in males the speckled nature revealing the presence of follicles is prominent. The follicles in males obtain a definite shape, either oval or rounded. Spermatids are found near the basal membrane in the beginning and towards the centre at a later stage. A few of the gonads are found in the ripe phase. The masses of the active spermatozoa are arranged in radial streaks with the tails towards the centre of the lumen (Pl. I, fig. 3). In females the follicles of gonads in the active phase become enlarged and small oocytes with rounded distal ends are found attached to the follicular wall by their cytoplasmic 'stalks' and protruding into the lumen. The oocytes themselves enlarge in size and in some cases well formed free ova with large nuclei are found in the lumen in good numbers (Pl. II, figs. 1, 2). While active phase is the general condition a few are still found in the spent and resting phase.

October: As a result of the rapid growth of gonadal follicles during the previous month the gonads have become 'full' and 'plump' and form major part of the soft parts. The branching nature of the germinal epithelium is obliterated as a result of the fullness of the gonads and the external surface is somewhat glossy. The majority of the gonads are in the ripe phase with mature sperms and ova filling the enlarged follicles (Pl. I, fig. 2 and Pl. II, fig. 1). The follicles in males as well as females, are closely packed without any interspace, the vesicular connective tissue having been completely obliterated. Towards the end of the month all the clams have entered the ripe phase.

November: The gonads are gradually turning flabby and slightly loose in consistency. The cream or creamy white colour which is characteristic of the fully ripe gonads is turning dull grayish. This gives an indication that spawning has started. The follicles are shrinking in size and also there is a reduction in the bulk of the gametes present in the lumen of the follicles. While some follicles have partially extruded their gametes there are others in the same gonad which are yet unspent (Pl. II, fig. 3). In some follicles of males the lumen appears empty while the spermatogonial layer continues to proliferate fresh batches of gametes (Pl. I, fig. 4). In females ova are less numerous in the lumen and the follicular wall contains small oocytes in considerable numbers. Thus in the beginning of November the gonads are in the partially spawned phase.

Towards the end of November spawning has far advanced and majority of gonads are found in the spent phase. The follicles are ruptured in some cases while in others faint lines indicating the follicular walls are present. The lumen contains relict ova and sperms which will be cytolysed in due course by the phagocytic cells which now appear in the inerfollicular space (Pl. II, fig. 4). In some cases the phagocytic cells are found inside the lumen also. When the process of cytolysis and resorption is over the gonads enter into the spent and resting phase and the sex of the individual becomes indeterminable. The spent gonads become translucent.

December : Spawning continues further and clams in spent and resting phase increase in number. The gonads appear loose and translucent. The follicles have been completely disrupted leaving a hieroglyphic appearance. Deeply staining phagocytic cells are numerous all over the gonadal tissues. In a few cases formation of vesicular connective tissue has been initiated, thereby showing signs of recovery.

January (1963) *:* As a result of the active formation of vesicular connective tissues the translucency of the gonads is gradually lost and they are becoming opaque. Later, signs of initiation of gametogenesis are evident in some clams.

February : More clams have fallen into the active phase. Some individuals have entered the ripe phase and a considerable number is in the resting phase.

March : Those in indeterminable stages are slowly reduced in number. Ripe phase has also been reached by majority of the clams and a number of them show signs of partial spawning.

April : Ripe clams are on the increase owing to vigorous gametogenic activity. A considerable number of clams have entered the partially spawned phase.

May : Spawning is vigorous as is evident from the appearance of a larger percentage of clams in the partially spawned phase. The clams in the active phase are less numerous and those in the ripe phase show a decrease from the previous month as they have started spawning.

June : The spawning activity continues till the end of the month and thereafter a majority of the clams enter the spent and resting phase. Formation of connective tissue is also observed in some of them towards the latter part of the month.

July : In some clams remnants of the unspawned gametes are still present in the beginning of the month. Later, all of them enter the indeterminable stage.

Although the subsequent spawning cycle from August to December 1963, for which observations were made, followed the same pattern as the corresponding cycle in 1962 there were found slight variations in the time and intensity of gametogenesis and spawning. While in September 1962 gametogenic activities were observed in many cases and full and plump gonads were commonly met with, in September 1963 only very few clams were found in the active phase and full gonads were almost absent. Even where gametogenic activities were initiated the progress was very slow. The gonads had not attained the full or plump stage even as late as October, thereby indicating that the reproductive activity was very slow. Observations made during January-May 1964 with small samples indicated the reproductive cycle to be the same as for the corresponding period in 1963.

From the above observations it can be concluded that there is a very prolonged breeding period from November to June. There appears to be two peak periods of spawning, in November-December and May-June. There also seems to be a comparatively quiescent period in the month of January when spawning activity is not traceable. The processes of initiation of gametogenesis, maturation and spawning are not uniform or synchronous in the entire population. When some clams are in the resting phase others enter the active phase and some others the ripe phase. As a result, spawning is prolonged.

The smallest size at which the clam has been found to have developed the primary gonad is about 10 to 11 mm. With an average growth rate of about 1.6 mm. per month in the first year clams of this size can be expected to be of about 6 to 7 months old. Clams of about 13 to 14 mm. length were found to have mature sperms and ova and it can be presumed that maturity is attained at this size when they are about 8 to 9 months old.

The sex ratios of the population for the period August 1962—December 1963 are given in Table I. In the months when no indeterminables occurred *i.e.*, April and May, it is seen that the males and females are almost equally represented.

TABLE I

Sex ratios in the clam Donax faba

Month	Sample size	Males %	Females %	Indeterminables %
1962				
August ..	48	14.6	10.4	75.0
September ..	75	56.0	33.3	10.7
October ..	170	55.3	40.0	4.7
November ..	200	42.0	40.5	17.5
December ..	125	8.8	15.2	76.0
1963				
January ..	99	4.0	2.0	94.0
February ..	125	29.6	17.6	52.8
March ..	150	39.3	38.0	22.7
April ..	205	51.2	48.8	..
May ..	193	47.2	52.8	..
June ..	150	56.0	28.7	15.3
July ..	197	11.2	2.5	86.3
August ..	125	1.6	..	98.4
September ..	181	13.8	5.5	80.7
October ..	150	38.7	20.0	41.3
November ..	150	52.0	41.3	6.7
December ..	200	22.5	18.0	59.5

Discussion—Nayar (1955) has observed that *D. cuneatus* has a single spawning season from January to April, the peak of spawning being in April. The prevalence of a prolonged spawning period with two peaks for the present species *D. faba* which is closely related to the former, is of some interest. *D. cuneatus* attains sexual maturity when it is about 12 to 13 mm. in length and about 10 months old. The individuals do not appear to spawn more than twice in their life time as most of the clams perish after their second year. Coe (1955) has observed in the case of *D. gouldi* from the coast of Southern California that the first spawning takes place at the age of about one year or one-and-a-half years in the case of clams resulting from the late spawning. The spawning season extends from April to October or

November. The spawning period in this case appears to be quite prolonged as in most of the tropical bivalve species.

The cycle of gametogenesis and biology of spawning has been extensively studied with respect to some molluscan species of the temperate waters, such as *Crassostrea virginica* (Coe, 1938 ; Loosanoff, 1942 ; Loosanoff and Nomejko, 1951 ; Loosanoff and Davis, 1950, 1952 *a, b*), *Ostrea edulis* (Cole, 1941 ; Loosanoff, 1962 ; Davis and Ansell, 1962), *Mya arenaria* (Coe and Turner, 1938 ; Pfitzenmeyer, 1962, 1965 ; Shaw 1964, 1965 ; Ropes and Stickney, 1965) and *Mercenaria mercenaria* (Loosanoff, 1937 *a, b, c*) to mention only a few of them. These studies have shown that the species have more or less well defined spawning periods in nature in respect of the areas where they occur and that the process of maturation and spawning is controlled by temperature of the waters where the species live. The question whether there is or not a definite periodicity of spawning in the marine invertebrates of the tropical waters has been widely discussed by various workers. From the Indian waters the works on estuarine and marine molluscs (Rao, 1951, 1952, 1956 ; Abraham, 1953 ; Nayar, 1955 ; Rao *et al*., 1962 ; Durve, 1964*b*, 1965) have shown that the species fall into different categories ranging from the ones having a restricted spawning season, *e.g*., *Katelysia opima* (Rao, 1952) to those spawning more or less continuously throughout the year, *e.g*., *Crassostrea madrasensis* in Madras harbour (Rao, 1951). The present species *D. faba* has been observed to have a prolonged breeding period with two peak spawnings in a year, November-December and May-June. The peak spawning in November probably is induced by the lowering of salinity and temperature in the month from the comparatively high values in the immediately preceding months. In August to October 1962 as well as 1963 high values of salinity prevail and in November there is a drop in the value. It appears that the precipitation by the North-West monsoon which brings about a drop in salinity value acts as a stimulant for the spawning activity. As the salinity values increase after the monsoon gametogenesis and maturation take place and spawning also sets in and continues under high values of salinity. A similar instance wherein rainfall, by causing a drop in salinity, stimulates spawning is seen in the case of the oyster *Crassostrea gryphoides*. The South-West monsoon dilutes the salinity of the Kelwa backwaters where the species lives, from 28.59 to 13.15‰ in July and the oysters begin to spawn (Durve, 1965).

PERCENTAGE EDIBILITY

The term ' percentage edibility ' has been used in the following account to indicate the percentage ratio of the wet meat weight to the whole weight of the clam, following the works of Venkataraman and Chari (1951) and Durve (1954 *a, b*). The same ratio has been denoted by the term ' condition index ' by Ansell and Loosmore (1963). But the latter term has been widely used by other authors (Baird, 1958 ; Cooper and Marshall, 1963 ; Durve, 1964*a*) to indicate the ratio of the volume of the meat to the volume of the animal as a whole. Hence the term ' percentage edibility ' has been adopted here.

The quality of the meat of the clams, oysters and scallops has been known to undergo seasonal variations as they pass through various physiological phases due to feeding, maturation, spawning and recovery. Information on this aspect of shellfish biology is important as the preference of the consumer always lies on the fatty ones and a knowledge on the periods when the shellfish is in the best condition is essential to determine the seasons at which the shellfish could be harvested with advantage.

Methods—Weekly samples of clams for the period August 1962 to December 1963, were brought to the laboratory and left in sea water. The clams were individually taken out, wiped dry and weighed correct to a milligram. They were opened, sex noted down and the meats were then preserved in 5% sea water formalin. After a week the meats were gently pressed between folds of blotting paper to remove excess moisture to an uniform extent and weighed. From these data fortnightly mean percentage ratios of the meat weight to total weight for the whole sample and also for the different sexes were calculated (Table II).

Observations—A perusal of Table II shows that there are fluctuations in the mean values of percentage edibility ranging from 7.25 to 11.98 for the entire samples, 7.53 to 12.23 for males, 6.75 to 11.89 for females and 6.67 to 10.99 for those of indeterminable sex. Since the differences among the minimum and among the maximum values are not much and the trend of fluctuations in males and females is the same, in the following analysis the mean values for whole samples only have been considered.

The values are high (10.14 to 11.98) during the period August-October 1962. Beginning in November, there is a steady decrease in the values reaching 7.96 in December. From January 1963 it shows a little increase and attains 9.60 in February and again decreases to 8.54 in the first half of March. During the second half of March there is sudden increase in the values to 11.35 and until the first half of May the values are high. From the second half of May there is a steady fall in values reaching 7.79 in August. From this until the first half of November the values show slight increases with the maximum at 8.95 in the first half of September. After November the values are still lowered and the mean is at 7.70 in the second half of November.

The above observations permit a correlation of the percentage edibility values with the reproductive cycle of the species. The months in which high values of percentage edibility have been obtained appear to correspond with the periods when active gametogenesis is encountered in the clams or when the gonads are in full condition, as from August to October 1962. The fullness of the gonads, no doubt, contributes to the high values. The decrease in values from November corresponds with the onset of spawning in the clams. The sudden increase in values in March may be the result of a sudden spurt of proliferation and maturation of gametes as observed from the examination of gonads. With the beginning of peak spawning in May-June the values steadily decrease. The values obtained during August-October 1963 (maximum 8.95) are much less compared to the values for the corresponding period in 1962 (maximum 11.98). This can be explained by attributing to it the much less gametogenic activities observed in the 1963 season.

Discussion—The works of Rao (1956) on *Crassostrea madrasensis*, Durve (1964*a*, *b*) on *C. gryphoides* and *Meretrix casta* and Ansell and Loosmore (1963) and Ansell *et al.* (1964) on *Venus mercenaria* have shown that the 'condition' of the respective animals fluctuates closely following their reproductive cycles. Jones (1950) has also observed in the brown mussel (*Mytilus* sp.) that the condition of the gonads is mainly responsible for the fat or lean condition of the mussel. Cooper and Marshall (1963) have found in the case of *Aequipecten irradians* that crowding and competition for food are likely to adversely affect the condition. Ansell *et al.* (*loc. cit.*) have found the mean condition of *Venus mercenaria* in October and November 1962

TABLE II

Fortnightly variations in the mean values of percentage edibility in Donax faba

Month*		Sample size	Mean values of percentage edibility in			
			Whole sample	Males	Females	Indeterminables
1962						
August	II	25	10.73	11.14	10.89	10.68
September	II	45	11.98	12.23	11.89	10.99
October	I	50	10.89	10.79	11.46	9.70
	II	50	10.14	9.87	10.54	..
November	I	50	9.49	9.49	9.53	8.47
	II	50	8.22	8.25	8.83	7.47
December	I	25	8.02	8.47	8.27	7.82
	II	50	7.96	8.35	8.54	7.87
1963						
January	I	25	8.47	..	..	8.47
	II	25	9.28	10.01	9.86	9.11
February	I	25	9.60	9.59	9.91	9.54
	II	50	8.88	9.39	10.13	8.29
March	I	25	8.54	9.27	8.35	8.36
	II	50	11.35	11.04	11.63	..
April	I	50	11.37	11.31	11.34	..
	II	50	9.98	10.24	9.64	..
May	I	25	10.25	10.31	10.22	..
	II	75	9.36	9.48	9.20	..
June	I	50	8.59	8.53	8.73	8.30
	II	25	8.25	7.99	7.75	8.53
July	I	50	8.12	8.44	6.75	8.09
	II	49	7.90	8.41	..	7.48
August	I	25	7.79	..	..	7.79
	II	50	8.28	8.34	..	8.27
September	I	50	8.95	9.39	10.45	8.80
	II	50	8.19	8.59	9.27	8.01
October	I	50	8.21	9.07	8.13	7.77
	II	50	8.71	8.83	9.33	7.77
November	I	50	8.70	8.41	9.01	8.60
	II	25	7.25	7.53	7.16	6.67
December	I	50	7.69	7.56	7.59	7.84
	II	50	7.70	8.11	7.24	7.73

* The Roman numerals in this column refer to the two halves in a month.

to be considerably lower than that for the corresponding months of 1961. Such a situation has been met with in the present case also for the period August to October 1962 to 1963. The same authors have found a relationship between condition and size of the animals, indicating that larger individuals showed a different seasonal cycle from the smaller ones. But unfortunately such a relationship, if any, could not be established for the present species as the data on the smaller individuals were not sufficient.

The values of percentage edibility obtained for *D. faba* compare favourably with those of the Indian species for which data are available. *Meretrix casta* from the fish farm near Mandapam has a range from 4.22 to 5.98 (Durve, 1964*b*). This indicates a poor condition of the species in the particular environment. The same species from Madras has been found to have values from 5 to 16 (Venkataraman and Chari, *op. cit.*). Among the oysters, *Crassostrea gryphoides* has the values ranging from 1.28 to 8.75 (Durve, 1964 *a*) and *C. madrasensis* from 4.93 to 10.91 (Rao, 1956). Comparing with the size of the above bivalves, *D. faba* is much smaller, but gives values (7.25 to 11.98) which are higher than those of most others. The seasons when *D. faba* appears to be in the best condition are August to October and March to May.

Density of Population

A study on the level of abundance of the clams in the area of study was taken up to find out if there were changes in the abundance due to the well known causes such as natural mortality, fishing mortality etc. There was no intensive picking of the clams in this area and hence the data presented here can be taken to represent the natural level of abundance of the species in the area.

Methods—From December 1962 to November 1963, for a period of 12 months, monthly collections of all clams occurring in an area of one square meter near the mid water mark were made. The clams were collected by digging the sand down to about 20 cm. below which depth the species had not been found to burrow. Test sieves having apertures of 0.0395" and 0.0810" were used in sifting the sand.

Observations—From the data presented in Table III it can be seen that the density ranged from 89 per sq.m. in November to 217 in March. While clams above

Table III

Density of population of D. faba *as represented in an area of one sq. m.*

Group	1962 Dec.	1963 Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
Immature (13 mm. & below)	47	43	42	77	87	97	88	95	48	45	46	31
Mature (Above 13 mm.)	54	110	147	140	68	29	45	48	60	75	48	58
Total	101	153	189	217	155	126	133	143	108	120	94	89

13 mm. formed the majority in December 1962 through March 1963 and August through November 1963, the immature clams (below 13 mm.) formed the majority in April through July 1963. Resurgent populations have not so far been observed with regard to any of the Indian bivalve species, though a species of *Donax*, *D. gouldi* is known to be resurgent in the coast of Southern California (Coe, 1953, 1955). *D. faba* in the present locality appears to be comparatively free from pathogenic organisms such as the trematode, *Postmonorchis donacis* reported from *D. gouldi* which is known to affect large populations by bringing about death. Only a few ciliates were observed occasionally from the gonads of *D. faba*.

Summary

The environment in which the clam *Donax faba* was collected for this study has been described and the fluctuations in salinity and temperature have been recorded for the period, August 1962 to December 1963.

The clam completes one year of its life at the modal size of 19.5 mm. giving an average growth rate of about 1.6 mm. per month. In the first four months of the second year the clam shows a growth rate of about 0.75 mm. per month and attains 22.5 mm. Thereafter growth appears to be extremely slow and at the end of two years the size reached is 23.5 mm. only. The life span of the species does not seem to exceed 3 years.

The relationship between length and height and length and thickness are seen to be of the linear type and that between length and weight follows the cube-law.

D. faba appears to have a prolonged breeding period extending from November to June with two spawning peaks, November-December and May-June.

In clams of 10-11 mm. length development of primary gonad has been observed. When the clams reach 13-14 mm. they become sexually mature.

A close relation has been observed between the percentage edibility and the reproductive cycle of the clam. The values range from 7.25 to 11.98 and compare favourably with other bivalve species.

The population density ranged from 89 to 217 clams per square meter.

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