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OYSTER CULTURE—STATUS AND PROSPECTS

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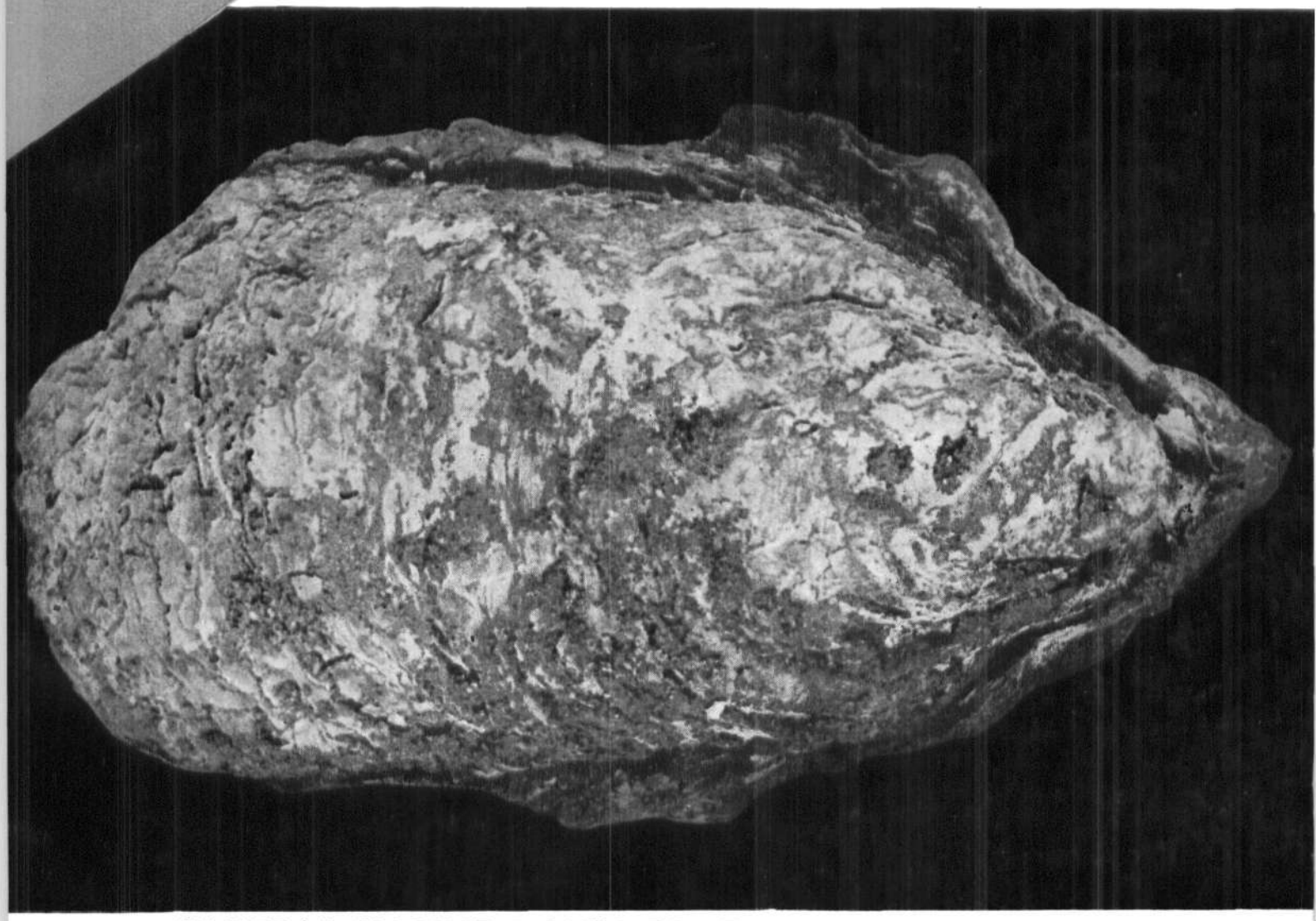

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BIOLOGY OF *CRASSOSTREA MADRASENSIS* OF KAKINADA

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INTRODUCTION

The concrete banks of the Kakinada canal harbour the oyster *Crassostrea madrasensis* (Preston) and they are particularly abundant at the mouth of the canal which extends and opens into the Kakinada Bay. The oyster beds are spread over an area of 2.25 ha and the oysters are regularly collected by the fishermen. Based on a survey conducted in April 1979, Narasimham *et. al.* (1984) estimated the density of the oysters in these beds at 112-1862 no/m^2 and the total stock at 90 t. There was no information available on the biology of *C. madrasensis* from the Kakinada Bay.

MATERIAL AND METHODS

During April 1985—July 1986, fortnightly samples of 60-250 oysters occurring in the subtidal region were collected at random from the oyster bed situated on the left bank (canal side) of the Kakinada canal. Also fortnightly water samples were collected from the oyster bed to study the temperature, salinity and dissolved oxygen. In the laboratory oysters were cleaned of all epifauna and epiflora with a wire brush and washed. Height was measured with a vernier calipers in the dorso-ventral axis, length in the antero-posterior direction and width from side to side in the broadest region when the valves were closed. The flesh was preserved in 5% formalin and examined about two weeks later. In the preserved oysters the sex and maturity stages were determined by examining the gonad smear under the microscope. The categorisation of the maturity stages was made following Ropes (1968). The gonad smears were studied in 20-25 oysters from each collection and a total of 760 oysters, of height range 37.5-95.2 mm were examined. Also histological preparations of gonad were studied in 120 specimens of height range 40.2-92.3 mm. Sections of 7-10 μ thickness were cut and stained in Delafield's haematoxylin and eosin. A test of variance for homogeneity was applied to examine whether the monthly sex ratio is uniform. The monthly sex ratio data were also analysed with the help of Chi-square test to see whether the sex ratio is different from 1 : 1 ratio.

The condition index was studied in 20 oysters from each collection and the overall height range was 25.0-94.4 mm. The flesh of each specimen was exposed to atmosphere for 1 h and then the still remaining moisture was removed with a blotting paper and then weighed. The dry flesh weight was recorded after keeping the wet flesh in hot air oven for 24 h at 90°C ± 1°C. The condition index was calculated as percentage of dry flesh weight in wet flesh weight.

Age and growth was studied by height-frequency analysis of 4,597 oysters measuring 6.0-102.7 mm. The oysters were grouped in 4 mm class intervals. To study the relationship between height and other body measurements the regression equation of the type $Y = a + bX$ was fitted by the least squares technique (Snedecor and Cochran, 1967). Where required logarithmic transformation was applied. A total of 64 specimens of height range 19.7-94.4 mm collected during April-June 1986 were used in these studies.

All linear measurements were taken to 0.1 mm accuracy, weight data above 5 g to the nearest 0.01 g and weight data of 5 g and below to the nearest mg. For various parameters the fortnightly samples were pooled and analysed on monthly basis.

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Results

(i) *Environmental conditions*

The monthly average temperature varied from 22.8°C in January, 1986 to 33.6°C in April, 1985 (Fig. 1). It was generally high in summer (April-May), low in winter (December-February) and moderate during the southwest and northeast monsoons (June-November). The salinity ranged from 3.49‰ in October, 1985 to 35.01‰ in May, 1986. It was high in summer, declined with the onset of southwest monsoon in June, reached low values in August-December as the southwest monsoon (June-October) was followed by the north-east monsoon (November-December); it began to rise in January to reach the peak in summer. The dissolved oxygen fluctuated between 1.80 ml/l in August, 1985 to 4.34 ml/l in April, 1985.

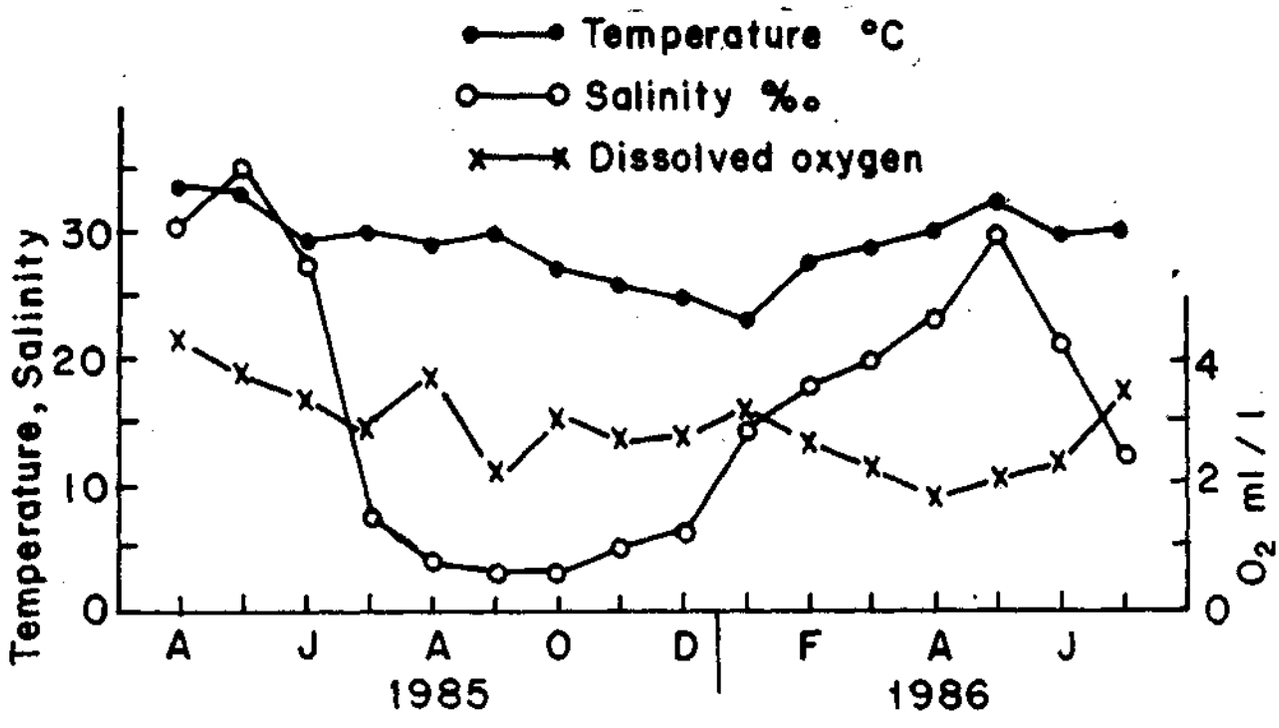

FIG. 1. Temperature, salinity and dissolved oxygen of the waters over the oyster bed in the Kakinada Bay.

(ii) *Maturity stages*

Active : The gonad is moderately developed and white in colour. Initially the follicles are few, small in size, mostly contracted and scattered in the connective tissue (Pl. I A). With further development they increase in number and are expanded. In males the follicles are packed with spermatocytes, spermatids and a few follicles may contain spermatozoa also (Pl. I B). In females oogonia appear at the periphery of the follicles, even before the gonads are completely empty. With further development the oocytes grow in size and are attached to the follicular wall by a stalk (Pl. II G).

Ripe : Gonad is well developed and cream coloured. Typically ripe gonads have dense appearence and the gametes are easily separated when punctured. In males the lumina of the follicles are densely packed with spermatozoa (Pl. I C). In females the follicles are packed with ripe ova which appear mostly free in the lumina. The ripe ova are polygonal or suboval in shape, measure 32-47 μ with nuclei 19-23 μ (Pl. II H).

Partially spawned : The gonad is pale brown in colour and the digestive gland is partly visible. When spawning is just initiated the gonad is well developed and with the progress in spawning it is reduced in size and becomes flabby. In both the sexes (Pl. I D, Pl. II I) there is a reduction in the number of gametes as they are discharged. This stage can also be called as spawning stage.

Spent/resting : In spent oysters the gonad is brown in colour and greatly shrunken. In both the sexes the residual gametes are present and connective tissue may be developing (Pl. I E, Pl. II J). In the resting phase the 'gonad' is well developed as it is filled with connective tissue and the oyster passes into indeterminate condition.

It was often observed that many follicles are not in the same level of development in the same specimen. For example in April-June, 1985 while majority of the follicles are in partially spawned stage others are mostly in active stage. In such cases the dominant maturity stage was assigned to the gonad.

(iii) *Spawning*

During April-June 1985, 80-95% of the oysters were in partially spawned stage indicating major spawning in these months (Fig. 2). In June most of the gametes were released. In July-October majority of the oysters (85-96%) were in spent/resting stage. Very few oysters (4-10%) were in partially spawned stage and among them most of the gametes were released. Gametogenesis was initiated in November and by December, 66% were in active, 26% in ripe and 8% in spawning condition.

In January-March, 1986 between 40 to 48% of oysters were in partially spawned stage; their number was reduced to 16% in April-May (Fig. 2). All the 4 maturity stages occurred in the above 5 months and their distribution suggests that the oysters undergo maturation and spawning more than once during these months; these months constitute the major spawning season. In June 2% and in July none of the oysters were in spawning stage and there was a progressive increase of spent/resting oysters in these two months indicating the completion of the reproductive cycle.

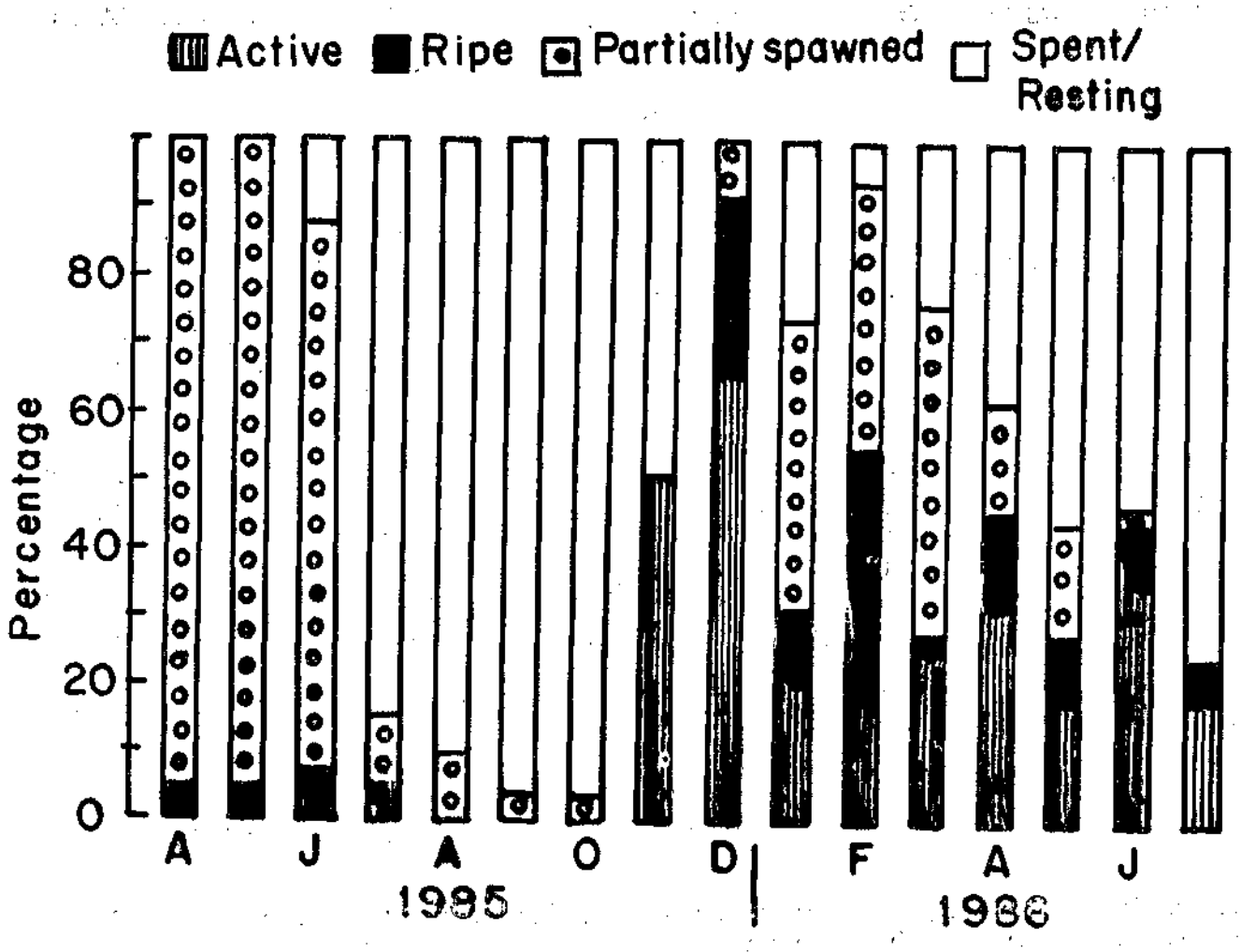

FIG. 2. Percentage occurrence of different maturity stages in *C. madrasensis*

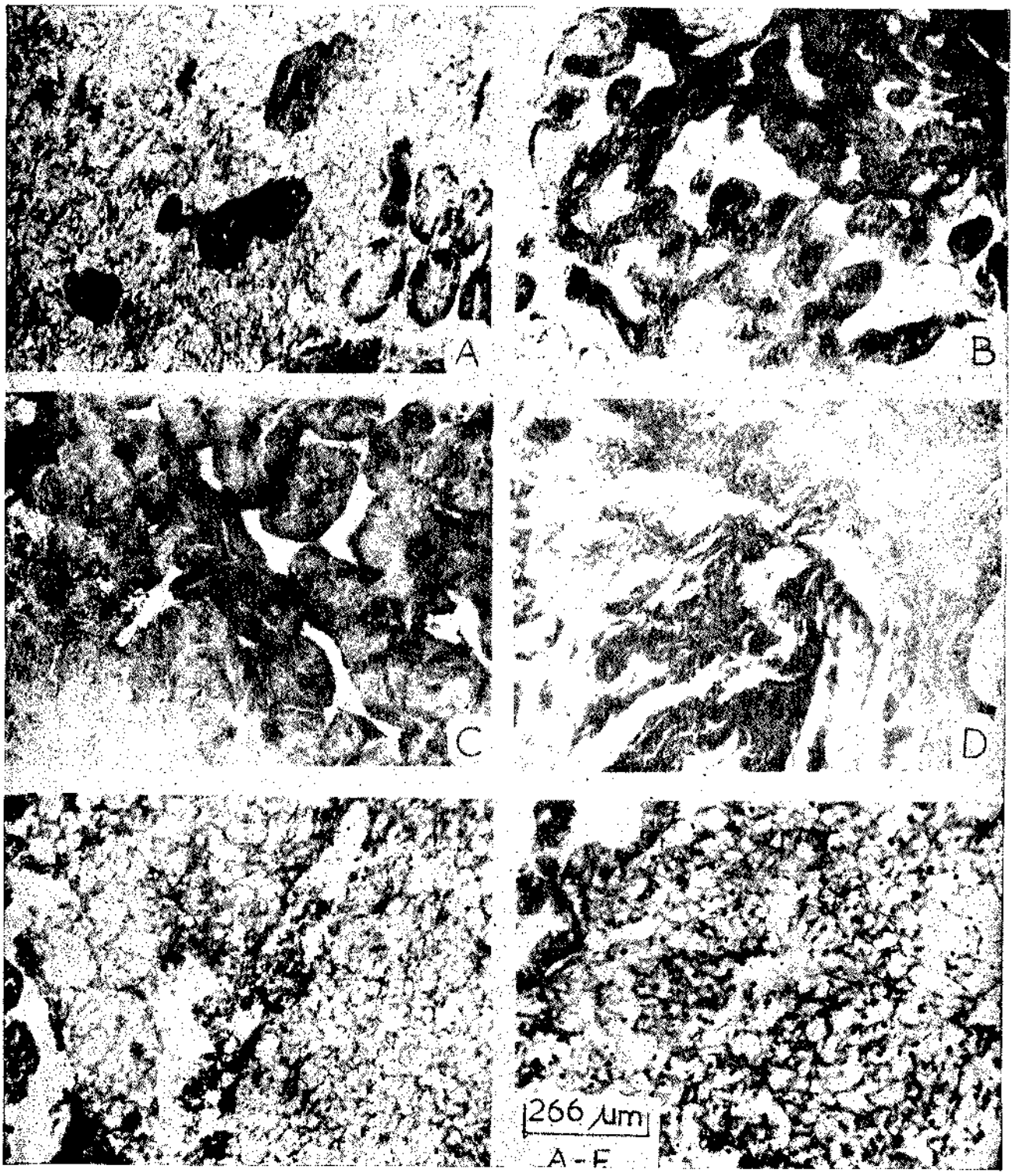

Plate I. A. Male gonad in early active stage showing a few follicles surrounded by connected tissue. B. Male gonad in active stage with many follicles and less of connective tissue. C. Male gonad in ripe stage. The follicles are expanded and densely packed. D. Male gonad in partially spawned stage. E. Male gonad in spent stage. Residual spermatozoa are present in the centre and the connective tissue is well developed. F. Resting condition. The connective tissue is well developed as the oyster passed into indeterminate phase.

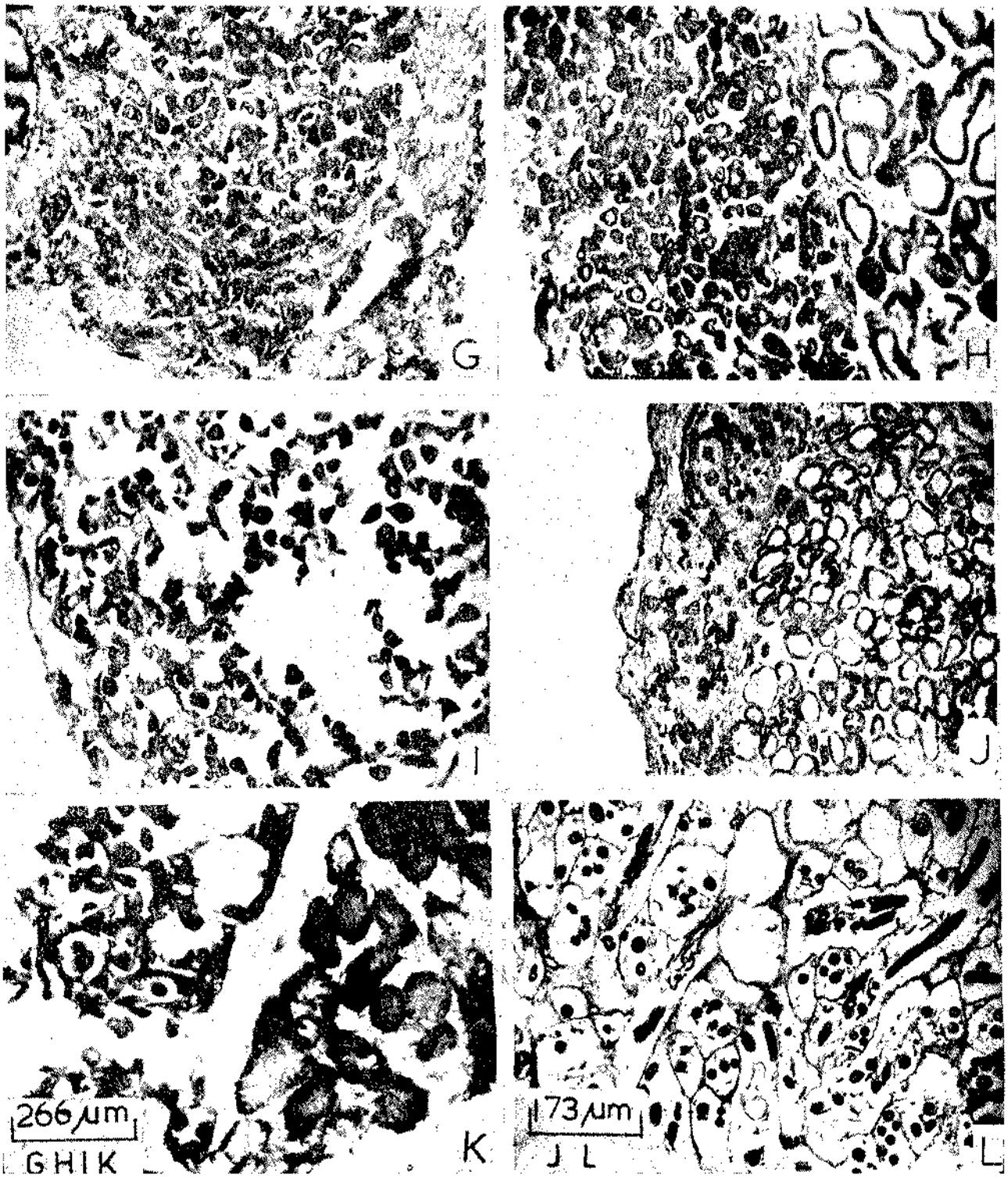

Plate II. G. Female gonad in active stage. The ova development is not uniform and the ova at top are far advanced in development than those below. H. Female gonad in ripe condition. The connective tissue is much reduced and many ova appear free. On the right is the digestive gland. I. Female in partially spawned stage showing some empty follicles. J. Shrunken gonad of a spent female. On the left are residual eggs which will be absorbed and on the right the digestive gland. K. Hermaphrodite showing ova on the left side and developing male follicles on the right side. L. Ovary infected by the bucephalid. Few eggs are present in the follicles.

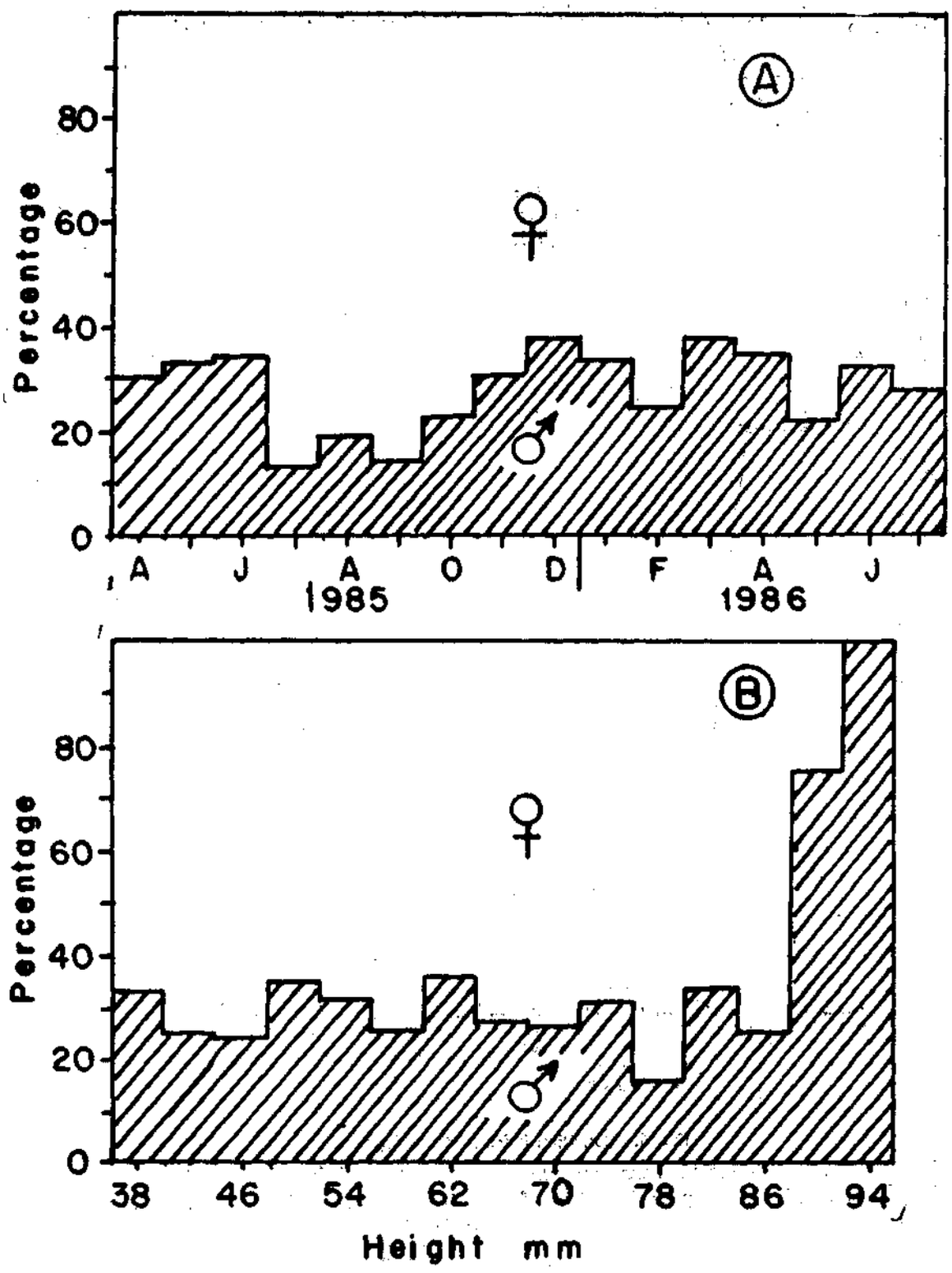

FIG. 3. Sex ratio in different months (A) and in different length groups (B) in *C. madrasensis*.

(*iv*) *Sex ratio*

Among the oysters which could be sexed, females invariably outnumbered the males in all the months and they formed between 62-87.5% during different months (Fig. 3A). The test of variance for homogeneity gave a Chi-square value of 17.78 (d.f = 1, 15) which is not significant at 5% probability. It was next ascertained whether the observed monthly sex ratio showed significant difference from the theoritical 1 : 1 ratio. The Chi-square values showed that at 5% probability there was a significant departure from the expected 1 : 1 ratio in all the months except in December, 1985 and March, 1986. It is concluded that the proportion of females is significantly higher than that of males.

The sex ratio in relation to height (Fig. 3 B) revealed that females outnumbered males in all the height groups excepting in 90 and 94 mm groups. However, the number of oysters examined in these two length groups were very few namely 4 and 1 respectively. The indeterminate oysters occurred in a few months and they formed 40%, 16%, 30%, 20%, 2%, 6.5% and 42% during July-November, 85, June, 86 and July, 86 respectively. During the study period males formed 24.3%, females 60.7%, indeterminates 9.5% and hermaphrodites 5.5%. Among the oysters which could be sexed the overall male : female ratio was 1 : 2.5.

(*v*) *Hermaphroditism*

Hermaphroditism was rare and 5% of the oysters were observed to the hermaphrodites (Pl. II K).

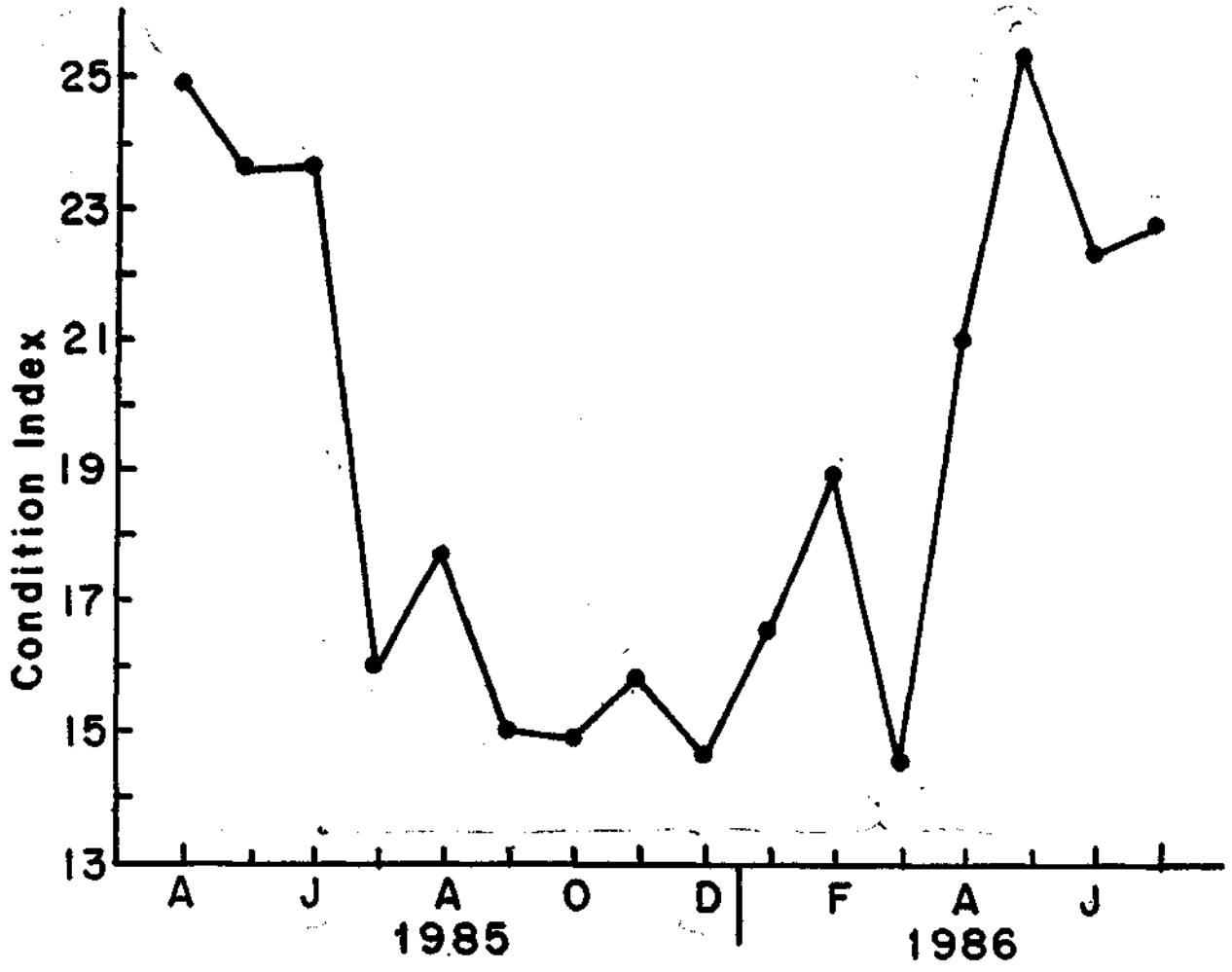

FIG. 4. Condition index in *C. madrasensis*.

(*vi*) *Pea crab infestation*

Two instances of infestation of the oysters by the pea crab *Pinnotheres* spp. were observed out of 840 oysters examined.

(*vii*) *Parasites*

Out of a total of 840 oysters examined the gonad of a single specimen was found to be infested by an unidenti-

fied bucephalid (Pl. II L). The gonad was distended with few eggs and the parasite invaded the digestive gland also.

(viii) Condition index

The monthly average condition varied from 14.5 in March, 1986 to 25.4 in May, 1986 (Fig. 4). It was high and ranged from 21.0 to 25.4 during April-June, 1985 and April-July 1986. There were two minor peaks in August 85 and February 86. In the remaining months it was low.

(ix) Age and growth

Mode A at 22 mm in April, 1985 (Fig. 5) was traced to 54 mm in August and there was no further progress till January when it shifted to 62 mm. By February, 1986 it moved to 66 mm and by May, 1986 to 70 mm. The oysters spawn during January-June and this mode can be taken to be the result of spawning early during the season i.e. January, 1985. Then it follows that in 6, 12 and 16 months the oysters attained 50, 62 and 70 mm height respectively. Mode B at 50 mm in April, 1985 progressed to 66 mm in July, 70 mm in November-December and to 74 mm in February, 1986. By taking the mode as the result of spawning late in the season i.e., in May-June, 1984, the oysters attained 58-66 mm height in one year and 70 mm in 20 months. Here also the modal progression was very slow during July-December. It is reasonable to consider that mode C at 22 mm in March, 1986 to be the result of spawning in January of the same year and in July, when 6 months old, the oysters attained 50 mm modal height. This study reveals that (1) the oysters grow fast during January-June and there was near cessation of growth during the second half of the year (2) a single year class may be represented by 2 broods and (3) in one year the oysters attain from 58 to 66 mm height.

(x) Height-weight and morphometric relationships

The regression equations fitted for various parameters are given in Table 1. The correlation coefficient (r) is very high for the various height-weight relationships indicating the goodness of the fit. The t test showed (Table 1) that the regression coefficients which ranged from 2.4110 to 2.6678 in equations 1-3 are significantly different from 3 at 1% probability indicating that the increase in total weight, shell weight and wet meat weight in relation to height of the oyster does not follow the cube law and that the growth is allometric. Similarly the t test showed (Table 1) that the b values in the height-length and height-width relationships are significantly different from 1 at 1% probability indicating the allometric growth of these body proportions.

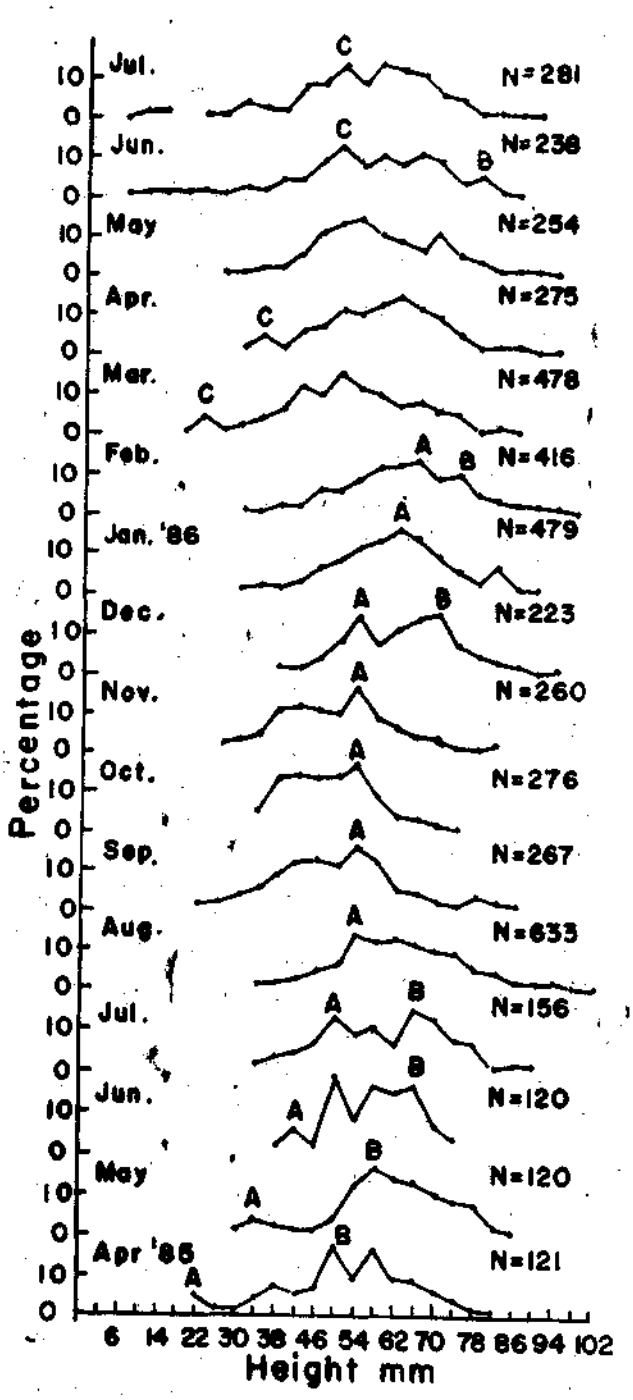

FIG. 5. Height frequency distribution in *C. madrasensis*.

TABLE 1. *Height-weight and morphometric relationships in* Crassostrea madrasensis. *Also the results of* t *test are given. The degrees of freedom is 62 for all the parameters.*

S. No.	Parameters		Equations		r	t
1.	Height (X) and total wt (Y)	..	Log Y=	−3.2421+2.6498 Log X	0.96	3.56
2.	Height (X) and shell wt (Y)	..	Log Y=	−3.3963+2.6678 Log X	0.95	3.13
3.	Height (X) and wet meat wt (Y)	..	Log Y=	−3.9245+2.4110 Log X	0.92	4.66
4.	Height (X) and length (Y)	..	Y=	7.5634+0.5823 X	0.84	8.74
5.	Height (X) and width (Y)	..	Y=	5.0008+0.2080 X	0.65	25.76

DISCUSSION

Earlier studies showed that in *C. madrasensis*, occurring under marine conditions, spawning takes place throughout the year (Paul 1942, Rao 1951) whereas in estuaries, either a restricted or biannual spawning was reported (Rao 1951, Rao 1974, Rao and Nayar 1956, Joseph and Madhystha 1982). In the present study, conducted in an estuarine environment, major spawning takes place during January-June. It is of interest to note that in the green mussel, *Perna viridis* also, which occurs on the oyster beds at Kakinada, major spawning takes place during January-May (Narasimham, 1980). Sastry (1979) reviewed the various exogenous and endogenous factors which influence the reproductive cycle in bivalves. Among them temperature and salinity received greater attention. At Kakinada, in both the oyster and green mussel, the major spawning period coincided with rising water temperatures and high salinities. During the non-spawning period, the temperatures were moderate and salinity was low. Joseph and Madhystha (1982) also observed that increase in salinity induces gametogenesis.

Rao (1956) observed that in *C. madrasensis* from Ennore backwaters males were dominant in January-June and females in the remaining months. However, in the present study the proportion of females was significantly higher than that of males in all the months and also in different length length groups.

Hermaphroditism in this species was observed by Rao (1953, 1956), Rao (1974) and Joseph and Madhystha (1982) and it was considered as a transitional stage to sex reversal (Rao, 1953). In this study also hermaphrodite oysters were encountered and they formed 5%.

There seems to be no other record except the present study regarding the infestation of *C. madrasensis* by the pea crab *Pinnotheres* spp. However, *C. gryphoides* and *C. cucullata* from Bombay showed pea crab infestation (Durve 1965, Awati and Rai 1931).

Infestation of *C. madrasensis* by bucephalid parasite seems to be rare in Indian waters, since apart from the present study, Samuel (1978) reported from Tuticorin.

In this study the condition index (CI) was high during April-June, 1985 when majority of the oysters were in partially spawned stage and with the completion of spawning it fell in July; it remained low during August-December when spent/resting oysters were dominant. In March majority of the gametes were released and the CI declined and with the progress of another reproductive cycle during April the CI was high. In June-July the majority of the oysters were in spent/resting stage and the considerably high CI in these months may not be related to the reproductive cycle. Rao (1956) also observed the fall in CI in this species following spawning.

Rao and Nayar (1956) observed that in the Adyar estuary *C. madrasensis* attains 50.6 mm height in 13 months. In the Bhimunipatnam backwaters Reuben *et al.* (1980) found that this species grows to 80 mm in one year; in the Mulky estuary it attains 91.5 mm in first year and 142 mm in second year (Joseph and Joseph, 1985) and in the Vellar estuary 48.81 mm, 84.97 mm and 111.7mm at ages 1-3 respectively (Somasekar *et al.*, 1982). In the Kakinada Bay this species attains 58-66 mm in one year. Thus considerable disparity in growth is discernible at different places. In the present study growth was slow during June-December when the salinities were very low. Similar observation was made by Rao and Nayar (1956) on this species.

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