

III

FISHERY AND BIOLOGY OF THE GREEN MUSSEL, *PERNA VIRIDIS* (LINNAEUS)

K. A. NARASIMHAM

The green mussel in the natural beds at Kakinada Bay attains an average length of 63 mm in 6 months, 92.2 mm in 1 year and 129 mm in 3 years. The mussel stock show a considerable variation from year to year, in spawning activity although it extends from December to July with peak activity in January to May. At Kakinada there appears to be no appreciable difference in the biological cycle of the farm grown mussels and those in natural beds.

INTRODUCTION

Most of the available literature (Ranade *et al.*, 1973, *Curr. Sci.* 42(16) 584¹, Nagabhushanam and Mane, 1975, *Bull. Dept. Mar. Sci. University of Cochin*, (2)377-387², Rao *et al.*, 1975, *Indian J. Mar. Sci.* 4 : 189-197³, Rao *et al.*, 1976, *Indian J. Mar. Sci.* 5(1) 113-116⁴, Wafer *et al.*, 1976, *Indian J. Mar. Sci.* 2 : 252⁵, Qasim *et al.*, 1977, *Indian J. Mar. Sci.*, 6 : 15-25⁶) concerning the rate of growth, reproduction and spawning behaviour of the green mussel of India relate to the population existing along the west coast. Precise knowledge of the biology of *Perna viridis* found in the east coast was considered essential to get an overall idea. The scientific information presented here is based on the results of investigations carried out at Kakinada.

MUSSEL BED AT KAKINADA

In the Kakinada area, at the mouth of the Upputeru canal which opens into the Kakinada Bay, there is a limited green mussel bed spread on granite stone embankments of the canal. Mussels are removed from this bed, mainly for local consumption as food and the annual production is estimated at 7 tonnes (Jones and Alagarwami, 1973, *Proc. Symp. Living Resources of Seas around India, C.M.F.R.I.*, 641-647⁷). The bed is a narrow one, with an average width of 3 m, spread on either side of the banks of the Upputeru canal. Mussels occur on the left bank upto 600 m stretch while on the right bank they are distributed upto a distance of 2.3 km, upstream from the canal mouth. Their distri-

bution is patchy ; they occur from intertidal to subtidal region, upto 3 m depth.

The mussel bed was surveyed in 1974 and an estimated 1,27,200 mussels weighing 11 tonnes were found in the 1.47 ha bed. The density varied from 0 to 20 mussels/m². The size range of the mussels varied from 27-160 mm.

Fishery

Fifteen fishermen, all belonging to Yetimoga fishing village (3 km from the mussel bed) are engaged seasonally during March-May in fishing the mussels from the Upputeru canal. Two or three of them set out in a plank built boat and pick the mussels by hand at low tide. A crowbar may be used to lift larger stones for collecting the mussels underneath. Diving also is resorted to often. Annually 5 tonnes are fished. The size range of the mussels collected varies from 60-160 mm and they are sold at Rs. 10 to 20 per 100 numbers, depending on the size. Compared to the magnitude of green mussel fishery at Calicut (Malabar Coast) the fishery at Kakinada is insignificant. Kuriakose (Personal communication Table 1) estimates an annual landing of 900 tonnes at Calicut.

The Upputeru canal, being navigation channel is regularly dredged and the dredged earth is dumped on the mussel bed. It is possible that this practice is denuding the bed of mussel population in recent years.

Environmental conditions

Surface temperature in the bay varies from 26°C in December to 33.5°C in April/May, then decreases

TABLE 1. Total mussel landings from Calicut to Mahe area during different months (in tonnes) (Kuriakose, Personal Communication)

Months	1975	1976	1977	1978	1979	Average catch in tonnes
January	74.40	161.00	97.84	37.95	112.80	96.79
February	53.88	178.08	142.50	32.00	147.40	110.77
March	75.60	191.32	93.15	34.40	131.20	105.13
April	81.82	175.03	48.60	31.00	119.00	91.09
May	63.64	145.75	..	10.20	93.00	62.52
June	..	..	..	..	..	..
July	..	..	..	..	..	..
August	..	..	..	..	..	..
September	70.65	109.80	30.97	..	..	42.28
October	94.83	174.00	46.97	106.00	108.62	106.08
November	174.73	210.00	30.91	255.00	104.48	155.03
December	167.81	244.00	49.60	153.00	82.65	139.41
Total	857.35	1,588.98	540.54	659.55	899.15	910.72

until September after which there is a rapid fall through December. The salinity ranges from 1.45‰ in October to 31.5‰ in May. It is moderate to high from January to August and low during the rest of the year. The dissolved oxygen in 1974 varied from 3.44 to 7.84 ml/l. In 1975 it ranged from 4.20 to 6.48 ml/l. The pH varies from 7.0 to 7.8 in 1974 (7.0 to 8.2 in 1975) and the water is slightly alkaline (Fig. 1).

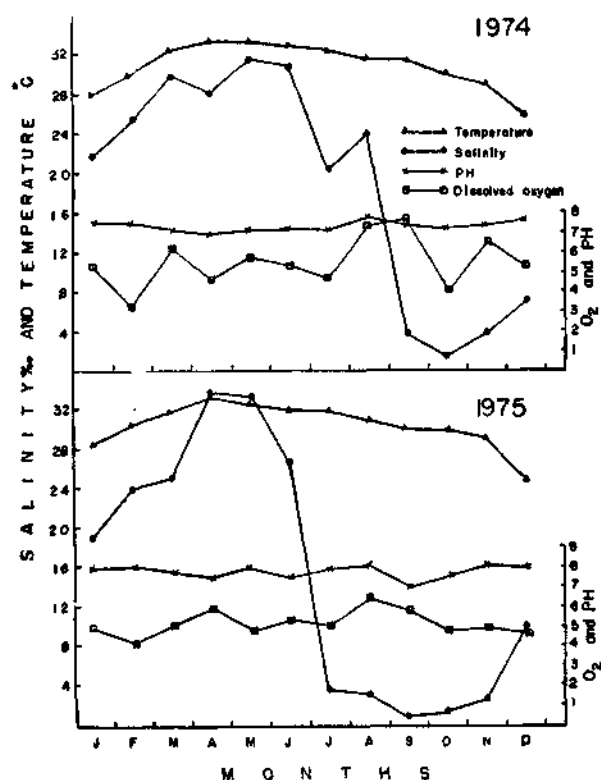


Fig. 1. Hydrographic data of the mussel bed.

AGE AND GROWTH

Natural bed : Length—frequency analysis

In this study only those modes which could be traced for an year or more were considered. The smallest mode 'E' measured 27 mm in February 1976 (Fig. 3). Rao *et al.*, (1975³) observed that in the laboratory the time required from fertilisation to spat settlement is under 3 weeks in *Mytilus viridis* (= *P. viridis*) and commented that it may be still less in nature. 10 mm spat of *P. viridis* reared in a cage at Kakinada grew to 26 mm in one month. Maturity studies indicated that 32% of the mussels from the natural bed were in spawning condition in December 1975. Based on these considerations it is reasonable to assume that the mode at 27 mm in February 1976 was the result of spawning in December 1975 and hence 2 months old. In June 1976 when 6 months old, it reached a length of 63 mm and could be traced to 87 mm by December 1976 when one year old. In September 1975 mode 'D' was present at 57 mm (Fig. 2) and it was allotted 5 months age since mode 'E' attained 63 mm in 6 months. Mode 'D' shifted to 69 mm by November 1975 when 7 months old, 93 mm by April 1976 when 12 months old and it could be traced to 111 mm by December 1976 when 20 months old. Mode 'C' appeared at 63 mm in August 1974 and was considered as 6 months old. It was traced to a length of 93 mm by February 1975 when 12 months old and 105 mm by August 1975 when 18 months old. Mode 'B' measured 93 mm in January 1974. It was considered as one year old based on the modal progression of 'C', 'D' and 'E'. It shifted to 105 mm in July 1974 when 18 months old, 117 mm in January 1975 when 2 years old and 129 mm

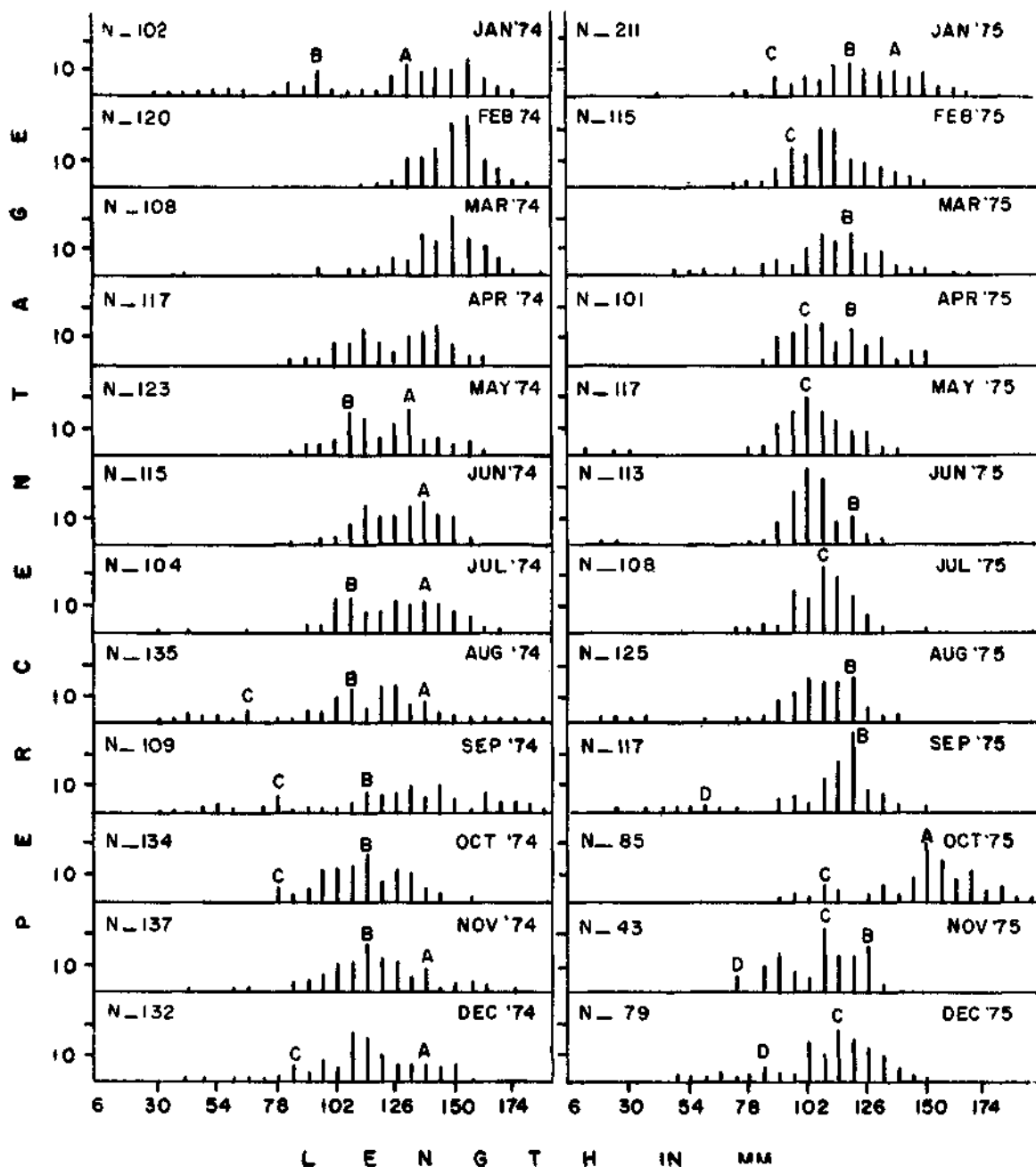


Fig. 2. Length-frequency distribution of *P. viridis* in 1974 and 1975. N indicates the number of mussels. Length group 0-6 mm indicated by 6 mm.

in January 1976 when 3 years old. Mode 'A' was present at 129 mm in January 1974 and it was considered as 3 years old since 'B' attained that modal length in 3 years. This mode progressed to 135 mm by January 1975 when 4 years old.

Based on the above observations in the natural bed the calculated average length at age are given in Table 2. It may be seen from the table that *P. viridis* attains an average length of 63 mm in 6 months, 91.5 mm in one

year, 107 mm in 1.5 years, 117 mm in 2 years, 129 mm in 3 years and 135 mm in 4 years.

Farm

In raft grown mussels, spat of 21.7 mm mean length noticed in collectors in May grew in 4 months time to 58.6 mm and in 5 months to 66.6 mm mean size giving an average rate of growth 9 mm per month. Since the size of the 21.7 mm mussels is about 2 mm—,

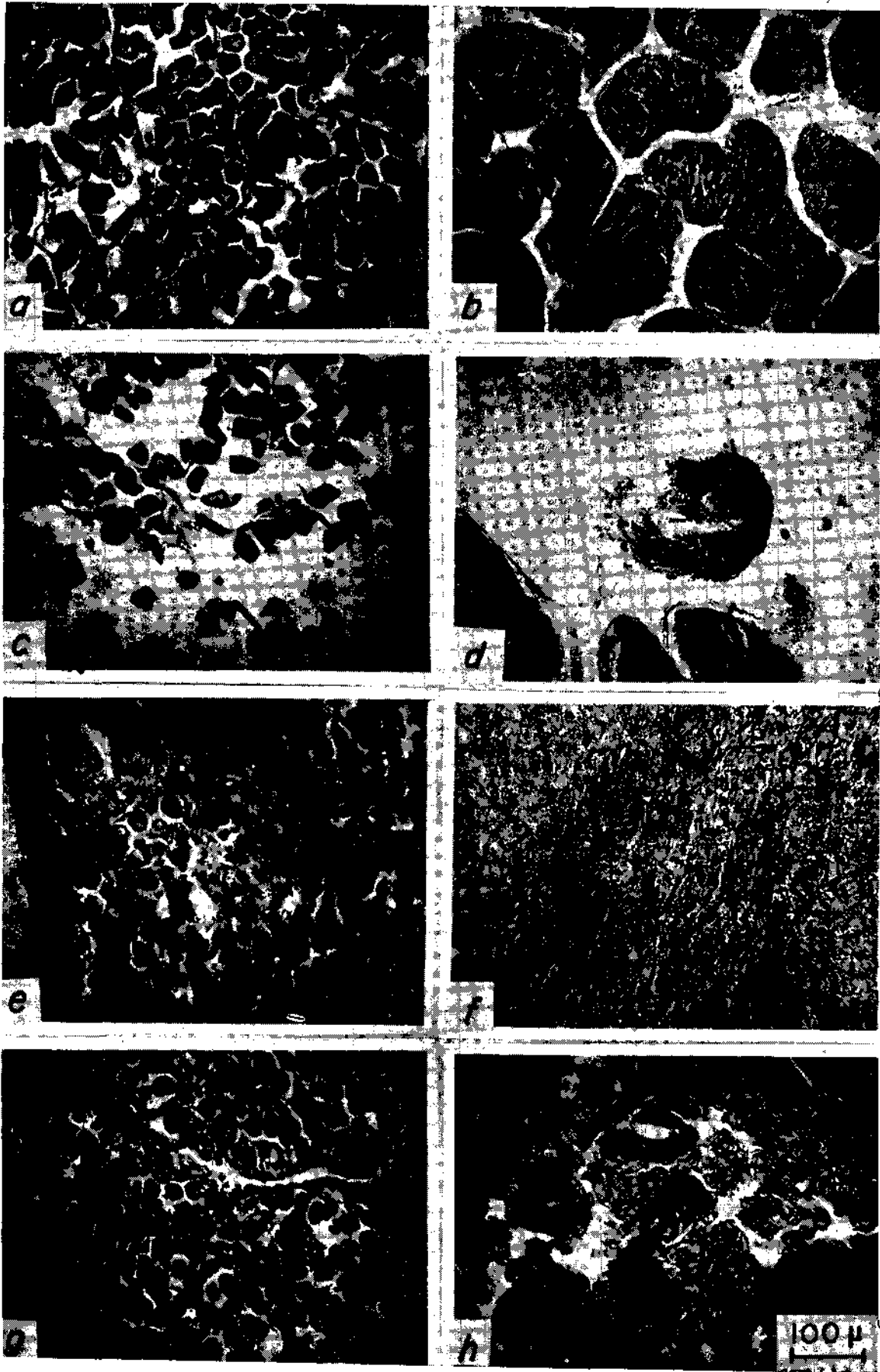


PLATE I. a and b. Fully ripe female and male gonads. c and d. Partially spawned female and male gonads. e. Spent female with few residual ova. f. Indeterminate gonad with interfollicular tissue. g and h. Developing female and male gonads.

the mussels attained a mean length of 58.4 mm in about 6 months. This growth is close to 63 mm in 6 months from natural beds.

TABLE 2. Modal lengths in mm in *P. viridis*

Modes	Years						Remarks
	0.5	1.0	1.5	2	3	4	
A	—	—	—	—	129	135	*Indicates the
B	—	93	105	117	129	—	calculated
C	63	93*	105	—	—	—	length based
D	63*	93	111	—	—	—	on the position
E	63	87	—	—	—	—	of the
							preceeding/
							succeeding
							modal length.
Average length	63	91.5	107	117	129	135	

REPRODUCTION AND MATURITY STAGES

Although mussels are known to be unisexual 0.8% were observed to be hermaphrodites. The

mature female can easily be distinguished by its bright orange red colour from that of the male which is cream yellow. Four main stages in the reproductive cycle are recognised viz. spent/resting, developing, ripe and spawning. In the spent/resting stage the sex may be distinguishable or indeterminate. In the recently spent mussels the gonad is shrunken, majority of the follicles are empty and few residual gametes may be present (Plate I, e). In the indeterminates the gonad may be moderately developed with enormous development of the connective tissue (Plate I, f). In the developing stage there is an increase in the gonad size and it is half the final size. Gametogenesis begins and the follicles contain developing gametes (Plate I, g & h). In the late developing condition the gonad is two-thirds its final size and the follicles contain both developing and ripe gametes. In the ripe stage the gonad is fully distended. In females the ova are ripe with narrow stalk and fill practically all the intervesicular space (Plate I, a). In males the follicles are full with ripe sperms (Plate I, b). In the spawning stage, with the emission of gametes the gonad becomes flabby and a reduction in the density of ripe gametes is evident (Plate I, c & d). In the mostly spawned condition the gonad is shrunken and the follicles contain few ripe gametes.

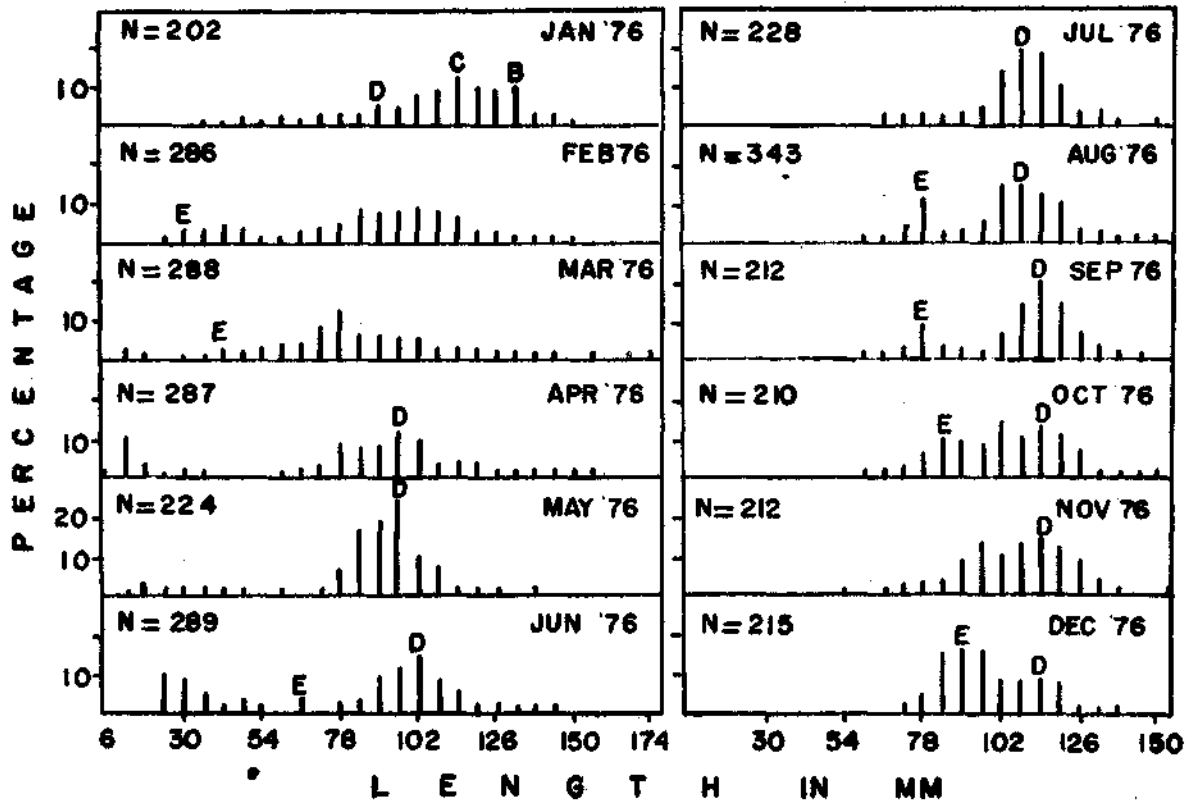


Fig. 3. Length-frequency distribution of *P. viridis* in 1976. N indicates the number of mussel. Length group 0-6 mm indicated by 6 mm.

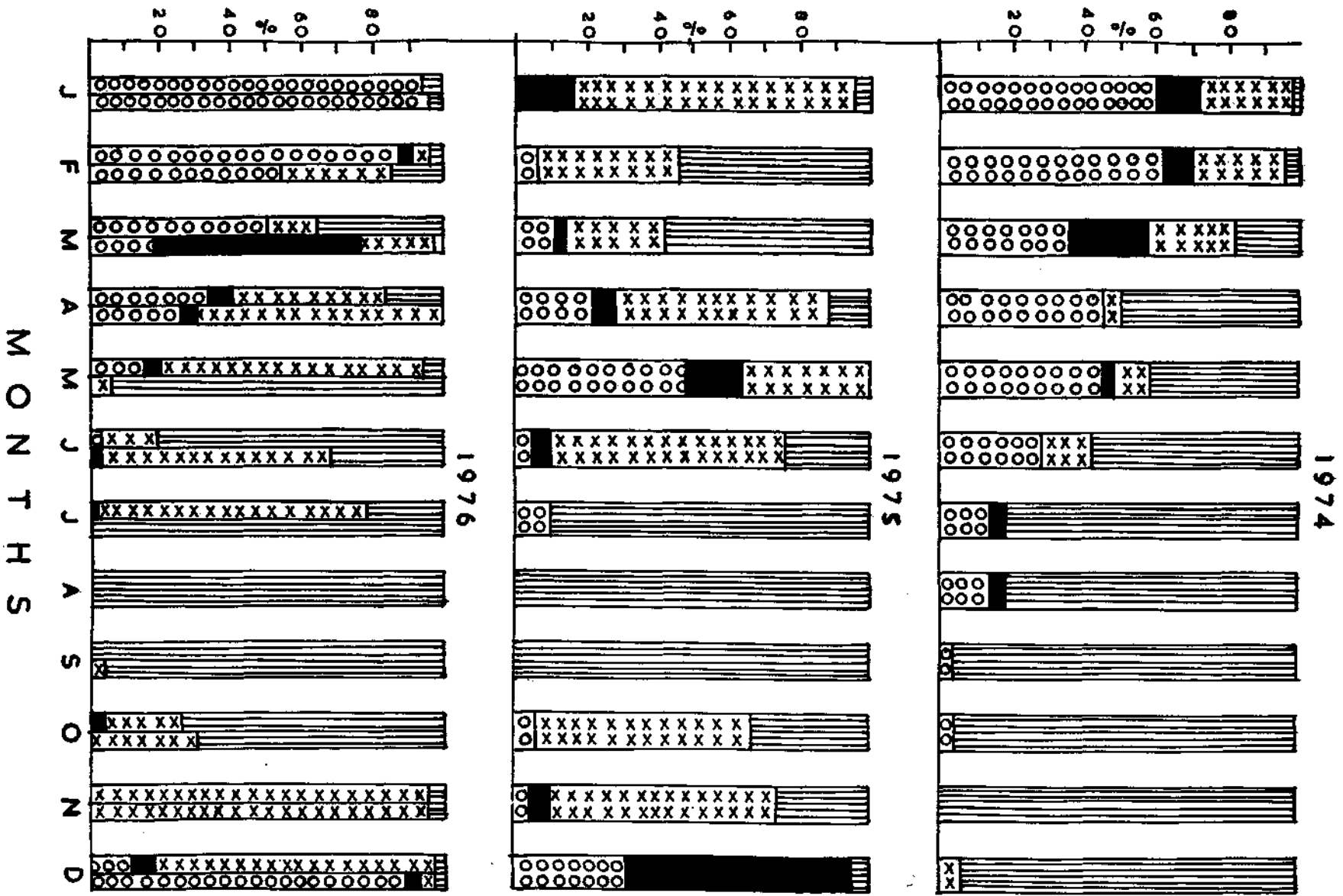


Fig. 4. Percentage occurrence of different maturity stages in *P. vitidis* (Vertical stripes-spent/resting, crosses-developing, shadertype and circles-spawning). During 1976 the maturity stages for the 2 fortnights of a month are shown separately.

Spawning

The percentage occurrence of different maturity stages are given in figure 4. In 1974 about 60% of the mussels were in spawning condition in January and February. During the March-June period the percentage of spawning mussels varied from 28 to 46 and this was further reduced to 14 in July and August. During the remaining four months there was no spawning except for isolated cases. Thus the spawning period is prolonged extending from January to August with peak spawning activity at the beginning of the season. Concurrent with the reduction in the number of spawners there was an increase in the number of spent/resting mussels from June onwards until November when all the mussels were in the resting stage. In December, gametogenesis was in progress in 6% of the mussels while the remaining were resting.

In 1975, spawning commenced in February when 6% of the mussels were in this condition. The number of spawning mussels increased to 12% by March, 22% by April and peak spawning activity was noticed in May when 48% of the mussels were in spawning stage. In June and July the number of spawners was reduced to 4 and 8% respectively. In August and September all the mussels were in spent/resting condition. Again there was minor spawning activity in October-November and by December while 64% of the mussels were ripe, spawning was in progress in 32%. The spawning period in 1975 differs from the preceding year in that the spawning commenced late; the peak activity was attained late. There was spawning in December and above all the intensity of spawning was low as revealed by the low percentage occurrence of spawning mussels.

During 1976, peak spawning activity was attained in January and February when 98 and 54% of the mussels respectively were spawning. In the following three months there was a rapid reduction in the number of spawners and by June only 4% of the mussels were in spawning stage. In the June-October period spent/resting mussels predominated while in November vast majority (96%) were in developing stage. Spawning commenced in the first quarter of December and by the month end 93% of the mussels were in spawning stage. The spawning in 1976 has much similarity with the events in 1974 except that during June-August there was no spawning in 1976. Both in 1975 and 1976 there was spawning in December. Thus the spawning period in the mussels at Kakinada is prolonged, usually extending from December to July with peak activity in January-May.

Ripe gonads were found in mussels measuring 22 mm onwards and most of the mussels attained sexual

maturity at 28 mm length when they are about 2 months old.

INDEX OF CONDITION

The trend in the values of the index of condition (termed IC) studied by the four methods (indicated in Fig. 5) is essentially the same except for a few anomalies observed in some of the values, particularly in the IC based on the meat weight—total weight ratio. This may be due to the varying quantities of water retained in the mantle cavity of the mussel which would affect the total weight. The IC of the mussels can be studied by adopting any one of the other three methods, provided uniform procedures were followed. However, the study of the IC based on the dry meat weight—wet meat weight ratio is time consuming.

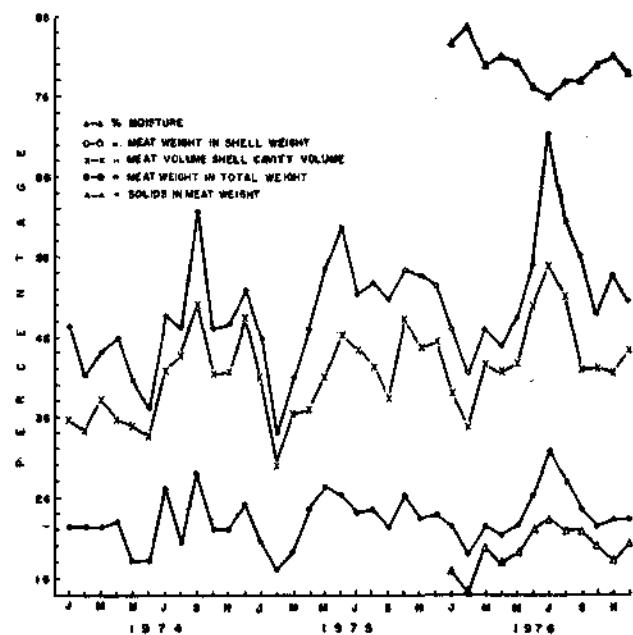


Fig. 5. Percentage moisture and index of condition in *P. viridis*.

In 1974 the IC fluctuated during January-April, dropped low in June and showed high values during July-December. There was a major peak in September and a minor one in December. In 1975 the IC was very low in February and generally high in May-December. A major peak was obtained in June, followed by a minor one in October. In 1976 also very low IC was recorded in February. This was followed by a minor peak in March. The IC values were high during May-September with a prominent peak in July.

The data suggest that, in general, the condition index was low in February and high during the second half of the year.

The percentage of moisture varied from 76 to 84.2 and showed an inverse relationship with the condition index (Fig. 5).

DISCUSSION

Paul (1942, *Proc. Indian Acad. Sci.*, 15B : 1-42⁸) observed that *M. viridis* (= *P. viridis*) grows to 14.5, 34.5, 52, 77.5 and 103 mm in 30, 84, 164, 241 and 445 days respectively in the Madras harbour. Ranade *et al.*, (1973¹) stated that in Ratnagiri waters the green mussel spat which measured 8 mm in October 1972 had grown to 61 mm in May 1973 giving an average growth rate of 7.55 mm/month. These data compare favourably with the results obtained at Kakinada. Rao *et al.*, (1975⁹) found that the green mussels reach 60 mm length in about 6 months on floating buoys. They further observed that on the natural bed the mussels reach 96, 132 and 156 mm in 1, 2 and 3 years respectively. Kuriakose (Personal Communication) reports that the growth at Calicut in the first year reaches 72 mm, in the second year it progresses by 38 mm and the third year increment is 10 mm. Qasim *et al.*, (1977⁶) noted that the mussels grow at about 8 mm/month on ropes. These observations are generally in agreement with the growth of the green mussel at Kakinada except that the length-at-age arrived at by Rao *et al.*, (op. cit⁸) for the 2nd and 3rd year mussels were on the higher side.

In the present study it was observed that growth in the mussels was fast in the first 6 months and slow in the second half of the year. While the range in the temperature variation was only 8.5°C the salinity showed much pronounced variations. Fast growth was recorded during the period when the salinity was high and the temperature showed a rising trend touching peak in April-May. Poor growth was noticed when the salinity was low and the temperature showed a rising trend touching the lowest in December. Various factors like temperature, salinity, light, food supply etc., were known to affect the growth of mussels (Seed, 1976, *Camb. Univ. Press publ.* (Ed.) *B.L. Bayne* : pp. 13-60⁹). In temperate countries growth is rapid in spring and summer and slow or absent in the cold winter months and this seasonal pattern in growth is generally attributed to temperature. The temperature requirements for optimum growth are known to vary and higher temperatures beyond the optimum have resulted in slow growth (Coe, 1945, *Jour. Exptl. Zool.* 99 : 1-14¹⁰). Also temperature alone could not be isolated as a controlling factor for the growth of mussels (Seed, 1976⁹). Among the various factors, high salinity and raising temperature seem to accelerate the growth of the green mussel at Kakinada.

Rao *et al.* (1975⁹) stated that the green mussel breed throughout the year along the Goa coast. Paul (1942⁸) arrived at similar conclusion regarding the spawning period of the same species in the Madras harbour. Nagabhushanam and Mane (1975⁹) have recorded two spawning periods at Ratnagiri ; one from June to early September and the other a minor one in February-March. Kuriakose has stated that spawning in natural beds at Calicut starts in July and extends to November, with a peak in August to October (Personal Communication). At Kakinada the spawning season in the green mussel was observed to be prolonged from December to July with considerable differences between the years. Various stimuli which can be grouped as exogenous and endogenous have been suggested as important in controlling the reproductive cycles of marine lamellibranchs (Seed, 1976⁹). Among them temperature has received the maximum attention. Increase or decrease in temperature are reported to induce spawning. Salinity changes are listed as equally important in estuaries and tropical waters. At Kakinada, peak spawning period (January-May) coincided with rising water temperatures and high salinities and the mussels were mostly in resting condition during the period when the temperature showed a decreasing trend and the salinity was low.

Paul (1942⁸) observed that a 15.5 mm green mussel contained ripe ova. Rao *et al.*, (1975⁹) stated that some mussels measuring 15.5 mm had ripe gonads and spawned in the laboratory. They further stated that ripe gonads were found in almost all the mussels at 25 mm length. In the present study the mussels seem to reach sexual maturity at a higher size (28 mm).

The index of condition is generally related to the reproductive cycle. The low value of IC in June 1974 may be due to completion of spawning in majority of the mussels. After the spawning the mussels recover to normalcy and enter the resting stage to become 'fatty' which accounts for the high IC in July-December. In February 1975 the IC was low for which the reasons are not clear. The high IC values in June-November 1975 could partly be related to the resting condition of the gonad after spawning. The low IC in February 1976 may be attributed to the progress of spawning. Again the high IC values in May-September may be due to the resting conditions of the mussels. Thus during the non-spawning period the index of condition was high. In the absence of knowledge about the biochemical changes associated with the condition it is difficult to interpret the fluctuations in the index of condition.

It may be mentioned that the very low salinities observed in October 1974 and September-October 1975 may not be typical for the months since the data were collected only once in a month. It is well known that in estuaries salinity variation is related to tidal cycle and freshwater drain. Since no mass mortality of the mussels was observed, it is presumed that these low

salinities prevailed for a very short duration so as not to adversely affect the mussels.

The best period for farming at Kakinada would be to seed the ropes hung from the raft during February-April and to harvest by September before the commencement of North-East monsoon.