STUDIES ON THE BIOLOGY OF *MACROBRACHIUM ROSENBERGII* (de Man) OF THE HOOGHLY ESTUARY WITH NOTES ON ITS FISHERY

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This paper embodies the results of an investigation into several aspects of biology of *Macrobrachium resenbergii* such as age and growth, length/weight relationship and fluctuations in relative condition with size and seasons of the year, sex-ratio, breeding, food habits, identification of young and their distribution in the Hooghly estuary. A brief account of the fishery of the species in the estuary is also given.

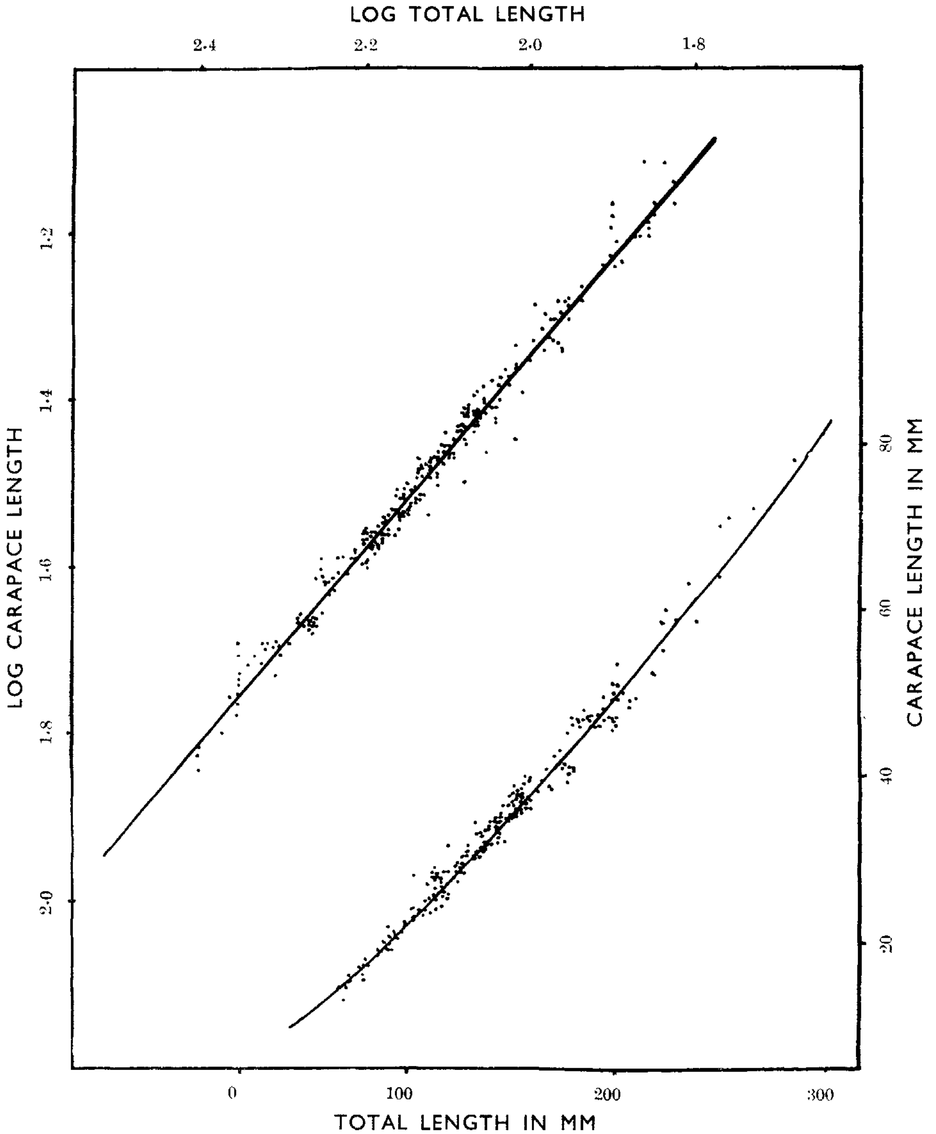
INTRODUCTION

The giant freshwater prawn, *Macrobrachium rosenbergii* (de Man), commonly known as *golda-chingḍi* in Bengal, is probably one of the biggest Natantians of the world. It reaches nearly a foot in length (Chopra 1943; Rajyalakshmi 1961), 'the large chelipeds of males adding another 17 to 18 inches in size' and is 'very common in lower reaches of rivers, lakes, *bils* and tanks in Bengal, Madras, Bombay, Sind and several other parts of the country' (Chopra 1943). Patwardhan (1937) has reported a giant male of three feet from Travancore from 'the tip of telson to the tip of the extended legs'. The species forms considerable fishery among Palaemonids in the freshwater and gradient zones of the Hooghly estuary. It also contributes a major share to the prawn component in *bheries* in Bengal, as also in the back waters of Kerala (Panikkar and Menon 1955).

Studies on maturation and fecundity in the Hooghly specimens and an account of age and growth of the species from the Ichamati River (Rajyalakshmi, 1961, 1964), observations on the life-history and bionomics (John 1957) and breeding behaviour (Rao 1965), description of some larval stages (Menon 1938) and location of a nursery ground in Kerala (Raman 1964) were the various aspects investigated so far in *M. rosenbergii* of India. This account embodies detailed investigations on all aspects of biology of *M. rosenbergii* of the Hooghly estuarine system. Studies on sex-ratio with particular reference to migration and mortality were also undertaken in these investigations.

Material and Methods

The material for the studies was derived from the regular samples of this species from the freshwater and gradient zones of the Hooghly estuarine



Text-fig. 1. Relationship between total and carapace lengths in *M. rosenbergii*.

system alone. In addition, periodically collected market samples at Nabadwip, an important market for prawns of the genus *Macrobrachium* in the freshwater zone, also constituted the material during the years 1962 to 1965

(Text-fig. 12). The material analysed was mainly derived from Traps (*Bithi* and *Duarbithi*), Bush (*Kumor*) and Light fishing, bag nets (*Been* and *Thor jals*), cast nets and others. The total length of the prawn was measured to the nearest millimeter, from the tip of the rostrum to the tip of the telson. The weights were taken nearest to the decigram in a double-pan 'trip type' balance. The specimens were preserved in five per cent formalin punched with perforations in the carapace region for better preservation of guts and gonads. In all, about 2,000 specimens were studied for the analyses of age and growth, length/weight relationship, food habits, sex-ratio and migration. Sex-ratios were calculated on the basis of specimens in which sex could be determined clearly by sécondary sexual characters. The post-larvae and juveniles were collected from shooting nets, small bag nets and fine-meshed *gamchas* operated in shallow canals of the river. Probable ages were determined separately for both the sexes. Probability plot method (Harding 1949; Cassie 1954) was utilized for the analysis of length frequencies into the constituent components of the polymodal distribution of the population. The merits and demerits of this method have been critically discussed by Pantulu (1962). Interconversions of total and carapace lengths of this species were based on 265 individuals for whom both the measurements were taken individually. The carapace length was taken with the help of a fine divider from 'the base of the eye notch to the posterior mid-dorsal edge of the carapace' (Cole and Mistakidis 1953).

Total Length/Carapace Length Relationship

Since measurements of total length are not possible in live specimens and in those with an incomplete, regenerating or broken rostrum, carapacial measurements in such cases were taken, as also in another big sample in which both carapace and total lengths were recorded for the estimation of the formulae for converting one into the other. Total and carapace lengths when plotted (Text-fig. 1) show a slightly curvilinear relationship. Hence, the logarithmic values of both the measurements were plotted in the graph and it was found that there is a straight line relationship between the variables. The scatter did not indicate the existence of more than one relationship which may be attributable to different sexes or more than one stanza of relationship attributable to different size or age groups. The formulae obtained were:

1. $\log. C.L. = -0{\cdot}92760 + 1{\cdot}13787 \log. T.L.$
2. $\log. T.L. = +0{\cdot}88675 + 0{\cdot}83088 \log. C.L.$

The value of the co-efficient of correlation (r) of the regression was estimated to be 0·97235 which is highly significant. Table I shows the carapace lengths and the observed and empirical total lengths calculated on the basis of formulae given above.

Age and Growth

In a few species of Indian prawns, lengths at different ages have been determined by the location of modes in the raw size frequency distributions (Menon 1951, 1953, 1955; George 1959; Kunju 1955). Such location of obvious modes, it is well known, may not always lead to an accurate interpretation of the true modal size of the component normal distributions. However, improved techniques adopted in recent years, of separating the component normal curves in a polymodal distribution, such as the probability plot technique (Harding 1949; Cassie 1954), can increase the accuracy in the determination of the modal lengths of size/age groups. In these studies, the age and growth rates were investigated separately for sexes. Due to the absence of hard parts of the body with periodic markings, it is generally difficult to estimate age and growth rate in Crustaceans with any degree of accuracy (Bhimachar 1965). However, to verify the conclusions on age and

Table I

Comparison of estimated and observed total lengths

Sl. No.	Carapace length (mm) observed (mean)	Total length (mm)	
		Estimated	Observed (mean)
1	10·2	53·07	48·0
2	13·7	67·79	67·7
3	16·1	77·54	75·2
4	17·7	83·09	83·6
5	20·2	93·56	93·8
6	23·9	107·60	105·4
7	26·0	115·40	115·4
8	29·2	127·20	124·0
9	31·2	134·40	134·6
10	36·1	151·57	144·8
11	37·1	155·20	154·4
12	38·3	159·30	163·1
13	41·3	169·50	174·9
14	46·4	187·70	184·1
15	47·1	189·20	191·8
16	50·5	200·40	202·3
17	51·1	202·40	213·3
18	57·8	224·20	224·3
19	60·8	233·90	233·0
20	70·5	264·40	252·0
21	78·0	287·10	287·0
22	81·0	296·80	300·0

growth, experimental rearing of live specimens was conducted at the Central Inland Fisheries Research Institute, Barrackpore.

In Table II are presented modal lengths, with their standard deviations, for males and females separately. Text-fig. 2 illustrates the normal curves fitted to the distributions. The size frequency distributions are found to be comprising of four normal curves for both the sexes. The first of these, which are 113·67 mm (T.L.) in males and 83·25 mm (T.L.) in females, were assigned to age one year. The fry collected during the months, May to July, by the operation of fine-meshed *gamchas*, shooting nets and small bag nets in the shallow depths of the canals of the river showed an average length of 15 mm in T.L. (range 10 mm to 20 mm) and these as seen from the progression of modal

TABLE II

Results of analyses of size frequency distributions by the use of probability paper

Calendar year	Males: Modal length (T.L.) in mm at years				Females: Modal length (T.L.) in mm at years			
	I	II	III	IV	I	II	III	IV
1963	108·5	146·5	223·0	—	77·5	133·5	153·0	210·0
(s.d.)	(26·63)	(18·43)	(42·10)		(15·87)	(15·74)	(18·50)	(5·78)
1964	123·5	142·5	—	—	89·0	129·5	161·0	220·5
(s.d.)	(14·39)	(19·97)			(12·37)	(14·79)	(25·29)	(18·56)
1965	109·0	137·0	229·0	261·0	—	118·0	159·0	232·5
(s.d.)	(10·89)	(17·89)	(13·18)	(11·84)		(15·6)	(40·35)	(18·29)
Mean	113·67	142·0	226·0	261·0	83·25	127·0	157·67	221·0

values in the Text-figs. 3 and 4 could have grown to 113·67 mm in males and 83·25 mm in females by the next April. Further, in the actual growth studies conducted by the author (Table III), the juveniles stocked in the cement cisterns, of dimensions of $180 \times 100 \times 70$ cm^3 of the Central Inland Fisheries Research Institute, and fed regularly with highly proteinous food in an easily digestible form, such as a special preparation of hen's or goose's eggs cooked in steam, grew to a mean incremental length of 88·6 mm in total length for both the sexes in one full year. This, more or less, corresponds to the one year length as estimated from the probability plot method. While making conclusions, it has been fully realized that under laboratory conditions growth of animals may not be the same as under natural conditions. The other modal values, namely 142·0 mm, 226·0 mm and 261·0 mm in males and 127·0 mm, 157·67 mm and 221·0 mm in females, were subsequently designated as II, III and IV years respectively. Table IV indicates the lengths at different ages for sexes with the corresponding values in carapace lengths and growth rates for each age for both the sexes and differences in lengths between the sexes of the same age. It is clear from Table IV that there is a difference in growth rates between males and females. During the second year in both

TABLE III

Records of fortnightly measurements of M. rosenbergii *of the experimental rearing of live specimens*

Sl. No.	Date of measurement	Carapace length (mm)		Calculated total length (mm)	Growth in length (mm)		Cumulative growth in length (mm)	
		Mean	(s.d.)		C.L.	T.L.	C.L.	T.L.
1	7-7-1964	4·107	—	15·00	0·000	0·00	0·000	0·00
2	—	—	—	—	—	—	—	—
3	3-8-1964	6·902	1·71	37·83	2·795	22·83	2·795	22·83
4	20-8-1964	8·554	2·00	45·83	1·652	8·00	4·447	30·83
5	4-9-1964	10·035	2·31	52·36	1·481	6·53	5·928	37·36
6	19-9-1964	11·234	2·55	57·46	1·199	5·10	7·127	42·46
7	3-10-1964	12·400	2·75	62·40	1·166	4·94	8·293	47·40
8	10-11-1964	13·141	2·85	65·49	0·741	3·09	9·034	50·49
9	21-11-1964	13·763	3·14	68·05	0·622	2·56	9·656	53·05
10	3-12-1964	13·768	3·38	68·25	0·005	0·20	9·661	53·25
11	18-12-1964	14·190	3·33	69·79	0·322	1·54	9·983	54·79
12	4-1-1965	14·190	3·66	69·79	0·000	0·00	9·983	54·79
13	18-1-1965	14·410	3·47	70·71	0·220	0·92	10·203	55·71
14	3-2-1965	14·450	3·78	70·85	0·040	0·14	10·243	55·85
15	17-2-1965	14·490	3·35	71·03	0·040	0·18	10·283	56·03
16	2-3-1965	14·890	2·27	72·66	0·400	1·63	10·683	57·66
17	18-3-1965	14·960	3·08	72·95	0·070	0·29	10·753	57·95
18	3-4-1965	15·612	3·23	75·56	0·652	2·61	11·405	60·56
19	19-4-1965	16·325	2·79	78·59	0·713	3·03	12·118	63·59
20	4-5-1965	17·424	3·15	82·77	1·099	4·18	13·217	67·77
21	18-5-1965	18·155	3·82	85·69	0·731	2·92	13·948	70·69
22	2-6-1965	18·542	3·33	87·18	0·387	1·49	14·335	72·18
23	19-6-1965	20·830	4·94	96·07	2·288	8·89	16·623	81·07
24	—	—	—	—	—	—	—	—
25	20-7-1965	22·825	2·91	103·60	1·995	7·53	18·618	88·60

the sexes and in III year in females, the growth rates are on the decline, which may be attributable to the breeding activity of the species. The general growth pattern, as revealed from the progression of lengths at different ages, appears to be more or less similar to the one propounded by Gompertz for fishes.

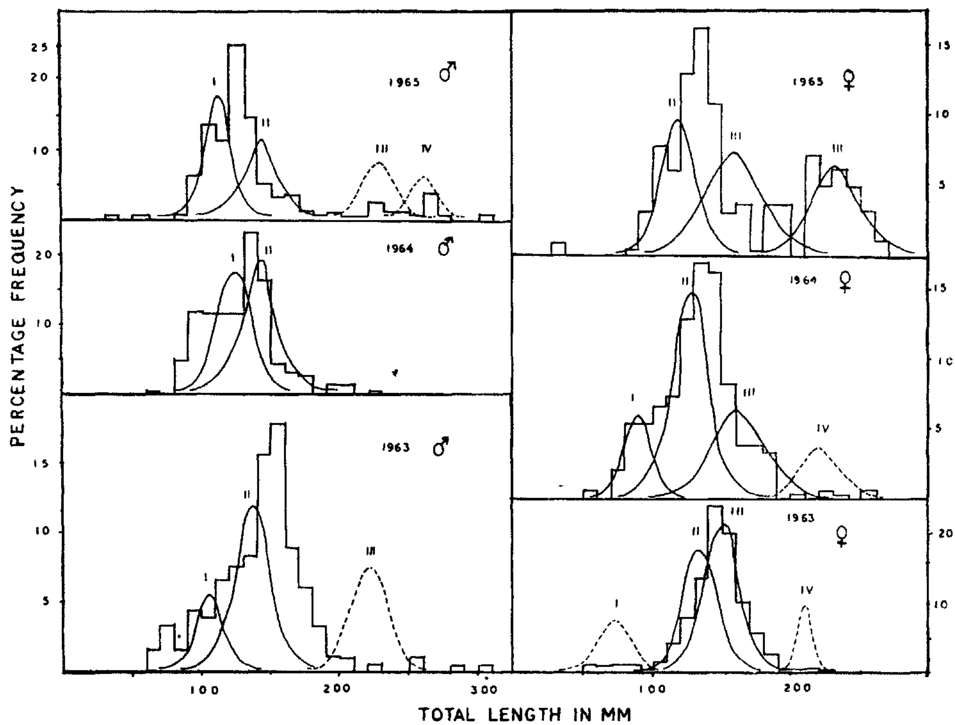
In Table III are presented fortnightly records of measurements of live specimens reared during July 1964 to July 1965. The growth rates during the

TABLE IV

Lengths at different ages, annual increments and differences between sexes of the same age

Age	Length in mm				Growth in length (mm)				Difference in length between males and females of the same age	
	Male		Female		Male		Female			
	T.L.	C.L.	T.L.	C.L.	T.L.	C.L.	T.L.	C.L.	T.L.	C.L.
1	113·67	25·79	83·25	18·09	113·67	25·79	83·25	18·09	30·42	7·70
2	142·00	33·32	127·00	29·26	28·33	7·53	43·75	11·17	15·00	4·06
3	226·00	56·37	157·67	37·44	84·00	23·05	30·67	8·18	68·33	18·93
4	261·00	66·40	221·00	54·95	35·00	10·03	63·33	17·51	40·00	11·45

winter months, November to February, are slower compared to the other months, which are associated with low temperatures during the period. There



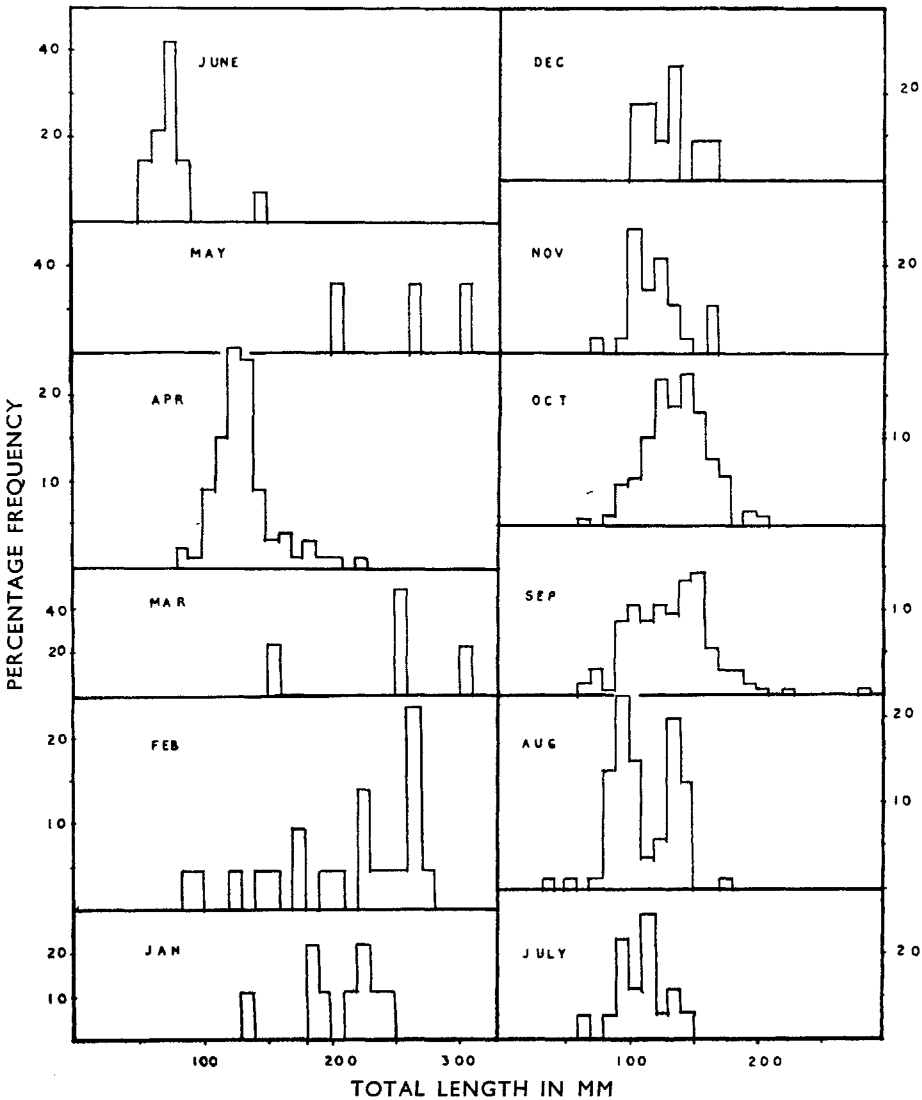
TEXT-FIG. 2. Length frequency distribution of *M. rosenbergii* during the years 1963 to 1965.

is a gradual rise in the value of the standard deviation with the increase in the mean lengths.

The maximum lengths in T.L., observed in these studies, were 310 mm (80·78 mm C.L.) for males and 267·0 mm (68·14 mm C.L.) for females.

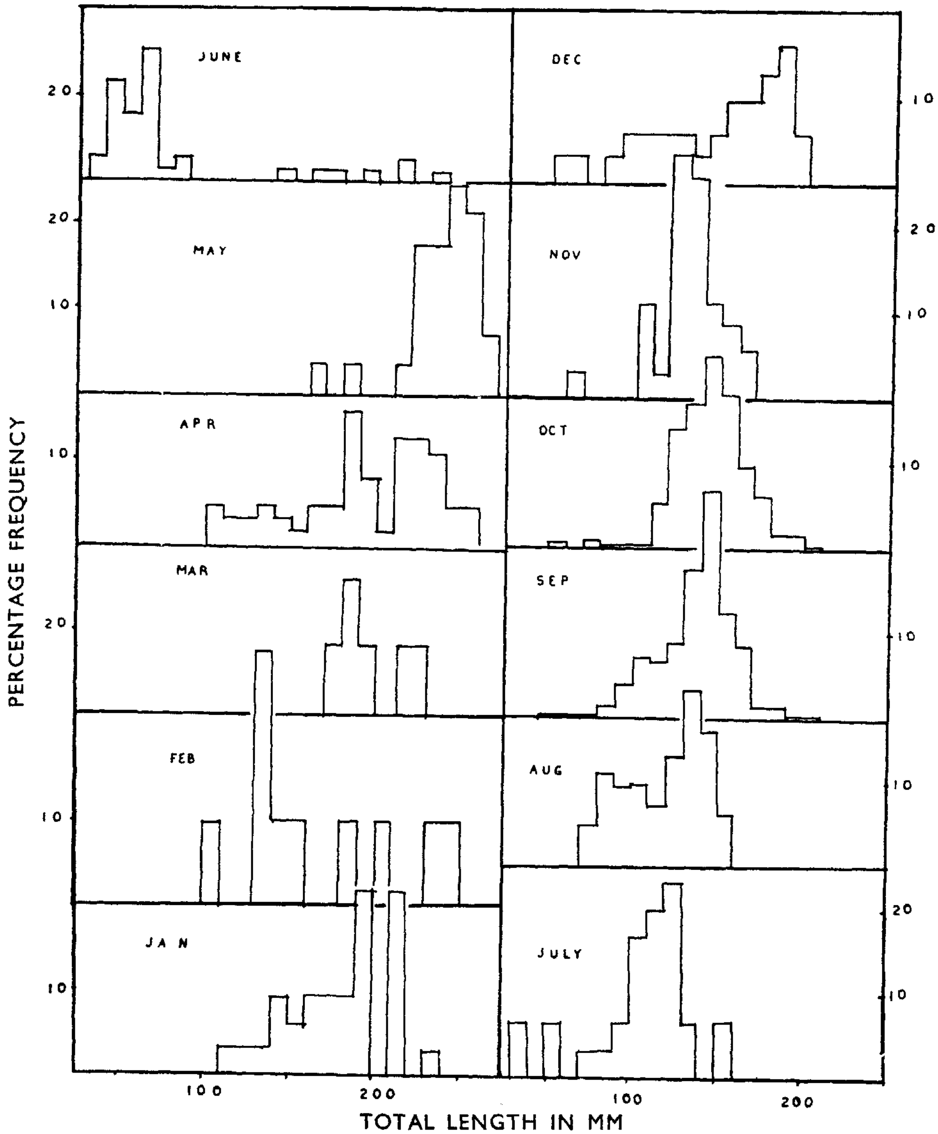
Length-Weight Relationship

The data used are based on 873 specimens of length range from 30 mm to 305 mm in total length. The weights of the prawns were taken with guts



Text-fig. 3. Length frequency distribution of males during different months—data pooled for the years 1962 to 1965.

and gonads intact. Both the sexes were considered together for computations, since the scatter diagram (Text-fig. 5) did not indicate different length-weight relationships between males and females. The lengths and



TEXT-FIG. 4. Length frequency distribution of females during different months—data pooled for the years 1962 to 1965.

weights were found to be related to each other linearly when plotted in the logarithmic values, conforming to the general formula, namely:

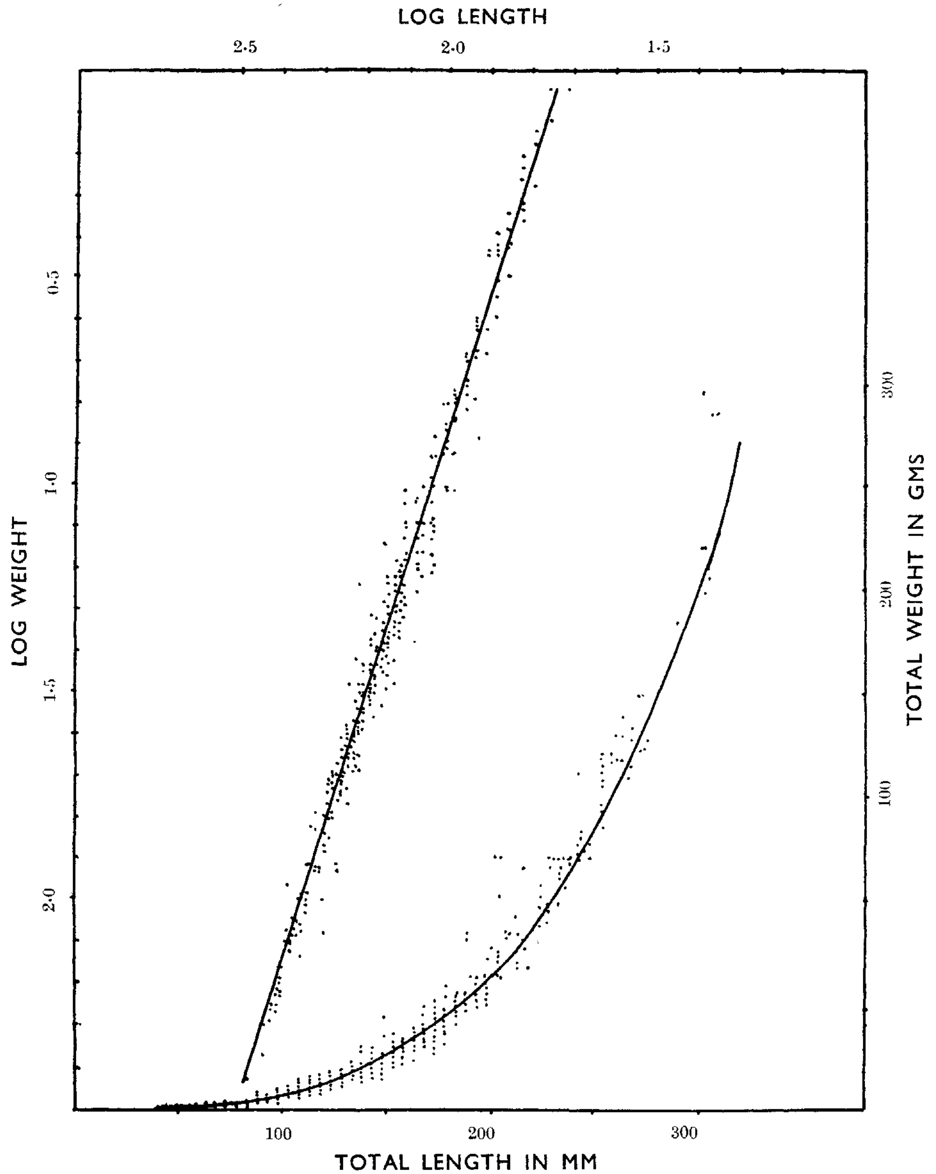
$$\log W = a + n \log L \text{ or } W = a\,L^n$$

The equation was calculated to be:

$$\log W = -5{\cdot}52748+3{\cdot}19346 \log L$$

or

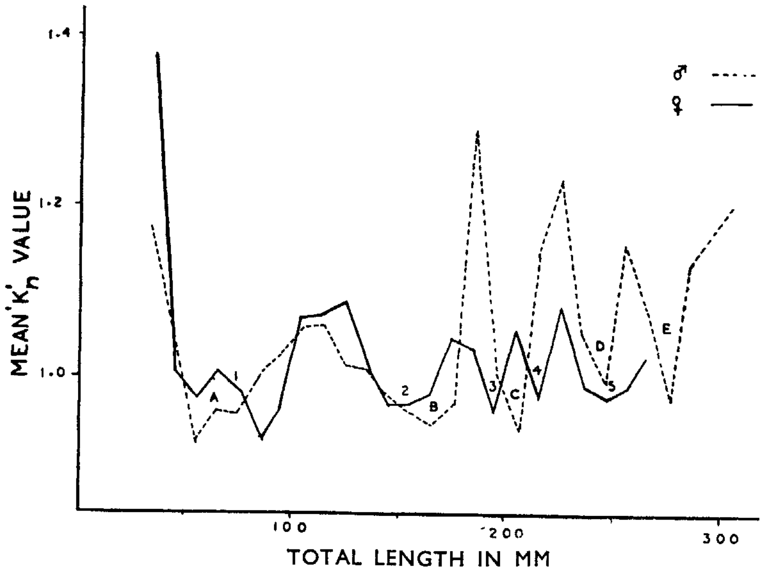
$$W = 0{\cdot}00007222 \times L^{3{\cdot}19346}$$



TEXT-FIG. 5. Length-weight relationship in *M. rosenbergii*.

The correlation of the regression was found to be very highly significant as seen from the value of co-efficient of correlation ($r = 0{\cdot}99013$). The equation conforms to the observation of Bhimachar (1965) that the values of n are above 3 in the case of freshwater prawns.

Relative condition.—The relative condition factor, K_n (Le Cren 1951), which is $W/\hat{W}$ (where W is the observed weight and $\hat{W}$ is the calculated weight) was calculated for each length group of 10 mm class interval separately for males and females (Text-fig. 6). The K_n was also computed for mature and immature individuals of each sex (Text-fig. 7) for each month. The preference of estimation of the relative condition to ponderal index ($K = W/L^3$) is very well known (Pantulu 1962).

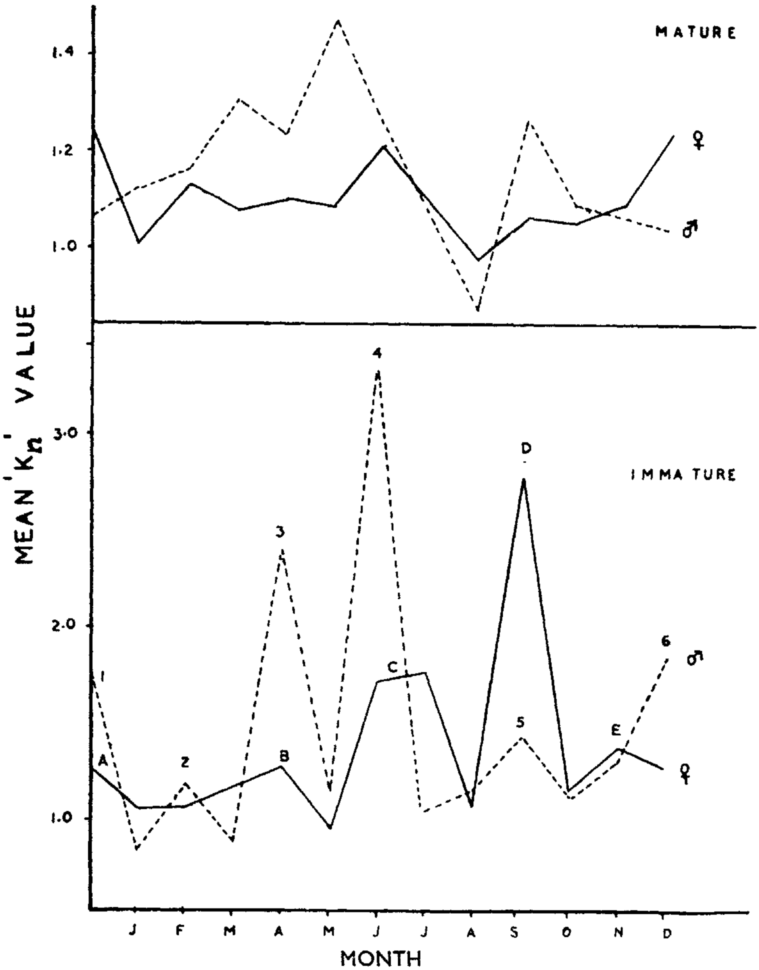


TEXT-FIG. 6. Mean relative condition values at different lengths.

Relative condition for different lengths:

Fluctuations in the relative condition with lengths (Text-fig. 6) appear to be more or less identical in case of both the sexes. It is evident from the figure that K_n is highest for the earliest observed size groups. Thereafter, fluctuations in condition are cyclic in nature showing several peaks followed by troughs. The first condition (1 and A, text-fig. 6) trough which is generally observed at 50 mm to 90 mm (T.L.) may probably be attributable to the migration of young ones from their rearing grounds in the estuaries to the freshwater zones. The stress resulting from the migration might have contributed to the lowering of condition at these lengths. The attainment of normal habitat in the environment of fresh waters may be responsible for the subsequent recovery in the relative condition. The low condition values observed in the second trough (2 and B, text-fig. 6) region which are followed by a steep rise may probably be attributable to the attainment of maturity.

Generally, in fishes a sudden drop in the K_n followed by a rise is associated with the attainment of maturity. Such an interpretation appears to be valid in case of prawns also, since it has been shown elsewhere in this account that 50 per cent levels in the maturity curves correspond to the lengths at 150 mm and 175 mm in females and males respectively. Subsequent valleys (3–5, *C–E*, text-fig. 6) and peaks in the relative condition curve may be attributable



TEXT-FIG. 7. Monthly fluctuations in the mean K_n values.

respectively to the elaboration of gonadial products prior to spawning and to the spent condition after spawning. Such cyclic nature in the relative condition curve has been interpreted to be a result of spawning and spent condition (Pantulu 1962). It is known that factors other than spawning, such as food, mainly affect the relative condition. In case of prawns, the amount of food ingested, when compared to the body weight, is so little that the food factor may not play such a major role as to affect the condition values. Le Cren (1951) found that nearly all the differences between seasonal values of relative conditions for mature and immature perch were due to cyclic changes in gonad weight.

Relative condition for different months:

For immature individuals.—Immature individuals alternate peaks and valleys in males and females, the extent being higher in males up to June and in females thereafter (Text-fig. 7). The probable reasons for the observed fluctuations are not easily evident. However, it is perhaps natural to expect such cyclic fluctuations because of the pattern of growth in prawns where the increments in length take place during the short ecdysis phase of the inter-moult cycle. Immediately after moulting, due to the absence of hard covering, water uptake due to imbibition takes place for increasing the volume of the body (Passano 1960), which factor results in an increase in weight and thus relative condition. Thus, perhaps, the peaks in K_n may represent the ecdyses phases, while the increase in weight takes place. Such an interpretation is perhaps inescapable in view of the fact that no other cyclic factors which may so spectacularly affect K_n are noticeable in immature prawns. Further, it has been shown that the percentage of full stomachs does not exceed 14·91 per cent in immature prawns. If the above interpretation is correct, then a study of relative condition may perhaps give an idea of the average number of moultings taking place in a year. Thus, the K_n of immature prawns have six condition peaks (1–6, text-fig. 7) in males and five in females (*A–E*, text-fig. 7) which may mean that males moult six times whereas females five times in a year (for immature prawns of above 30 mm in T.L. which are dealt here). The actual observations made in the experimental studies also broadly support the assumption on the number of moultings in immature specimens. Sex dimorphism in growth rates involving higher growth for males may probably be due to six moults in a year for males and a lower growth in females as a consequence of five moults in a year.

For mature individuals.—A plot of the relative condition values of mature individuals during different months (Text-fig. 7) exhibits two peaks with a trough in between. Both the sexes show the highest K_n values during the months March to May. These increments in K_n and attainment of peak values in both the sexes during March to May may probably be attributable to the elaboration of gonadial products consequent to the attainment of maturity during the peak of the breeding season, which, elsewhere in this account, was shown to be March/May months. Subsequently, the sudden steep which follows the first peak in the relative condition values during the months July and August in both the sexes may indicate the post-spawning phase and the spent condition in the breeding cycle. Thereafter, rise in the K_n values into the second peak denotes the recovery in the condition which appears to be more rapid in males than females.

TABLE V

Sex-ratios for different phases

Year	Number of males	Number of females	Total	Percentage of males	Percentage of females	Chi-square
(i) For different years						
1962	32	52	84	38·10	61·90	4·76*
1963	179	354	533	33·58	66·42	57·46
1964	226	329	555	40·72	59·28	19·12
1965	159	228	387	41·09	58·91	12·30
1962 to 1965	596	963	1,559	38·23	61·77	86·40
(ii) For mature and immature specimens						
Mature	68	331	399	20·54	79·46	172·36
Immature	528	621	1,149	46·04	53·96	7·52
(iii) For different ages (all years pooled)						
0 year	143	112	255	56·08	43·92	3·76†
I year	286	353	639	44·76	55·24	7·02
II year	130	334	464	28·02	71·98	89·68
III year	13	137	150	8·67	91·33	102·50
IV year	4	37	41	9·76	90·24	26·56
(iv) For different months (all years pooled)						
Jan.	9	32	41	21·95	78·05	12·90
Feb.	21	10	31	67·74	32·26	3·90*
Mar.	4	6	10	40·00	60·00	0·40†
Apr.	98	64	162	60·49	39·51	7·14
May	3	28	31	9·68	90·32	20·16
June	14	39	53	26·42	73·58	11·80
July	17	30	47	36·17	63·86	3·60†
Aug.	80	161	241	33·20	67·80	20·08
Sept.	124	223	347	35·73	64·27	28·24
Oct.	188	304	492	38·21	61·79	27·24
Nov.	27	35	62	43·55	56·45	1·04†
Dec.	11	31	42	26·19	73·81	9·52

* Significantly different at five per cent level (chi-square value above 3·841).

† Differences insignificant (chi-square value below 3·841).

Rest : Significantly different at one per cent level (chi-square value above 6·635).

SEX-RATIO

Studies on sex-ratio have been based on 1,559 specimens of length range from 30 mm to 310 mm in total length during the years 1962 to 1965. Percentages of each sex have been computed for each month, year, different ages and mature and immature specimens (Table V). Ratios were tested individually whether the observed deviations from the ratio of 1: 1 of the sexes on the 'null-hypothesis' are significant by the chi-square (χ^2) test (Snedecor 1956).

It can be seen from Table V (i) that, during the years 1963, 1964 and 1965, the differences in sex-ratios from 1: 1 are highly significant even at one per cent level and in the year 1962 the significance was at five per cent level. The percentages of males and females ranged from 33·58 per cent to 41·09 per cent and those of females from 58·91 per cent to 66·42 per cent during the years under study.

During the months, March, July and November, the chi-square values indicate differences to be insignificant from the equiproportional ratio of the sexes. In other months, except during February where the differences are significant at five per cent level, the differences in their proportions are highly significant (Table V, iv).

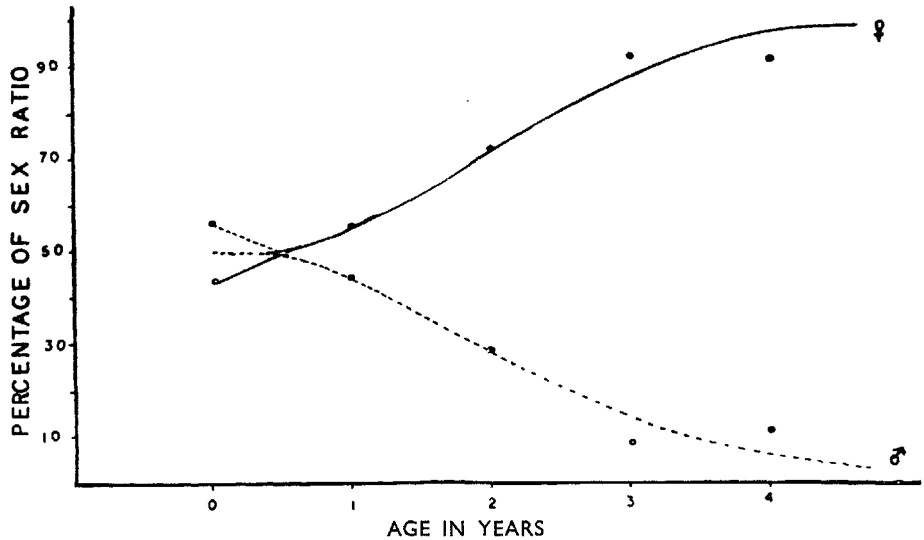
Sex-ratio and mortality:

The sex-ratios in percentages calculated for different ages of the population studied for the Hooghly estuarine system have been tested on 'null-hypothesis'. Only 0-year age group conforms to the equiproportional ratio even at one per cent level, while higher age groups are significantly different even at one per cent level. When the ratios in percentages have been plotted for each sex (Text-fig. 8) against the ages, the ratios in males have been on the constant decline, while those of females are on the increase. This, in a way, possibly denotes a higher rate of mortality in males than in females.

Sex-ratio and relation with migration:

For mature individuals.—Nabadwip, as stated previously, forms an important market for this species and is situated at the entrance of the freshwater zone of the Hooghly estuary (Text-fig. 12). A plot of the sex-ratios for this centre alone calculated for each month for males and females (Text-fig. 9) reveals differential proportions of sexes during different periods of the year. Males are predominant in February and again in September while females are more dominant from April to June and again from September to January than males. This shows that probably there are discreet shoaling habits of sexes, and males migrate downwards through Nabadwip centre earlier during February and females later during April to June for purposes of spawning. Abundance of females again during September to January and males in September may be as a result of the immigration of post-spawners from their breeding grounds, in males the backward migration being completed earlier by November. The total absence of the species in this region during the months June to August appears to indicate the spawning time of the prawn.

During the peak of the breeding season, March to May, almost only berried females are found in the spawning grounds, namely the Fuleswar-Ulubaria region of the gradient zone of the estuary. The absence of mature



TEXT-FIG. 8. Sex-ratios in *M. rosenbergii* at different ages.

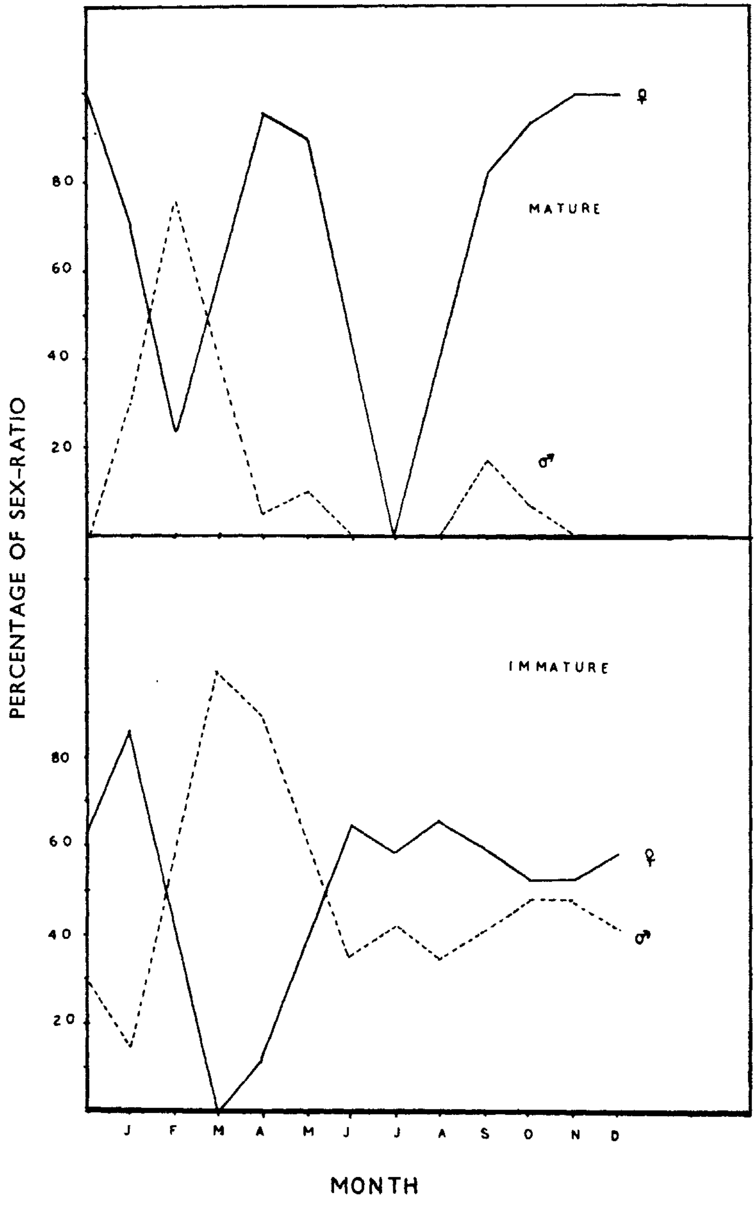
males during this period in the Fuleswar-Ulubaria region may probably denote the non-migration of mature males into this region from their freshwater habitats during the spawning season. From this it is evident that mating and early stages of incubation take place in the freshwater zone of the estuary (as seen from the occurrence of a few berried females even at Nabadwip centre) and spawning involving the actual hatching takes place in the gradient zone of the Hooghly estuary.

For immature individuals.—Percentages of immature males and females at Nabadwip centre alone (Text-fig. 9) show a similar trend of differential migration, the males appearing into the fishery earlier in January, while females enter later during March/April months.

Sex-reversal:

Live berried females collected from the vicinity of Barrackpore during June, 1965, after hatching out the larvae, were kept in the aquarium of the

Central Inland Fisheries Research Institute, Barrackpore, of dimension 180 × 90 × 120 cm³. Some of them totally changed into individuals showing male secondary sexual characters by September, after they passed through one to



TEXT-FIG. 9. Fluctuations in sex-ratios during different months at Nabadwip centre of the freshwater zone of the Hooghly estuary.

two post-spawning moults. Details of the individuals after they have changed the sex into males are presented in Table VI.

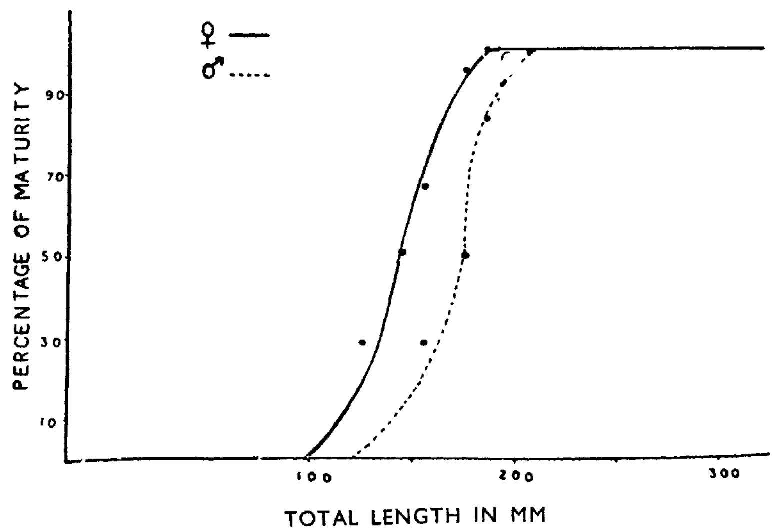
TABLE VI

Details of subjects after reversal into males

Sl. No.	Description	Case 1	Case 2
1	Carapace length	56·5 mm	43·5 mm
2	Cheliped (II) length	185·0 mm	133·5 mm
3	Genital flap and male aperture	present	present
4	Appendix masculina	present	present
5	Female genital pore	absent	absent
6	Ovary	nil	nil

RELATION BETWEEN SIZE AND MATURITY

Only individuals found during the spawning season, i.e. February to June, were considered. Females showing advanced stages of maturity of above stage III (Rajyalakshmi 1961) and in berry were taken into consideration and the presence of sperms in the gonads of males with well-developed secondary sexual characters are taken as indices of maturity. The relation between length and maturity is shown in Text-fig. 10. It is observed that

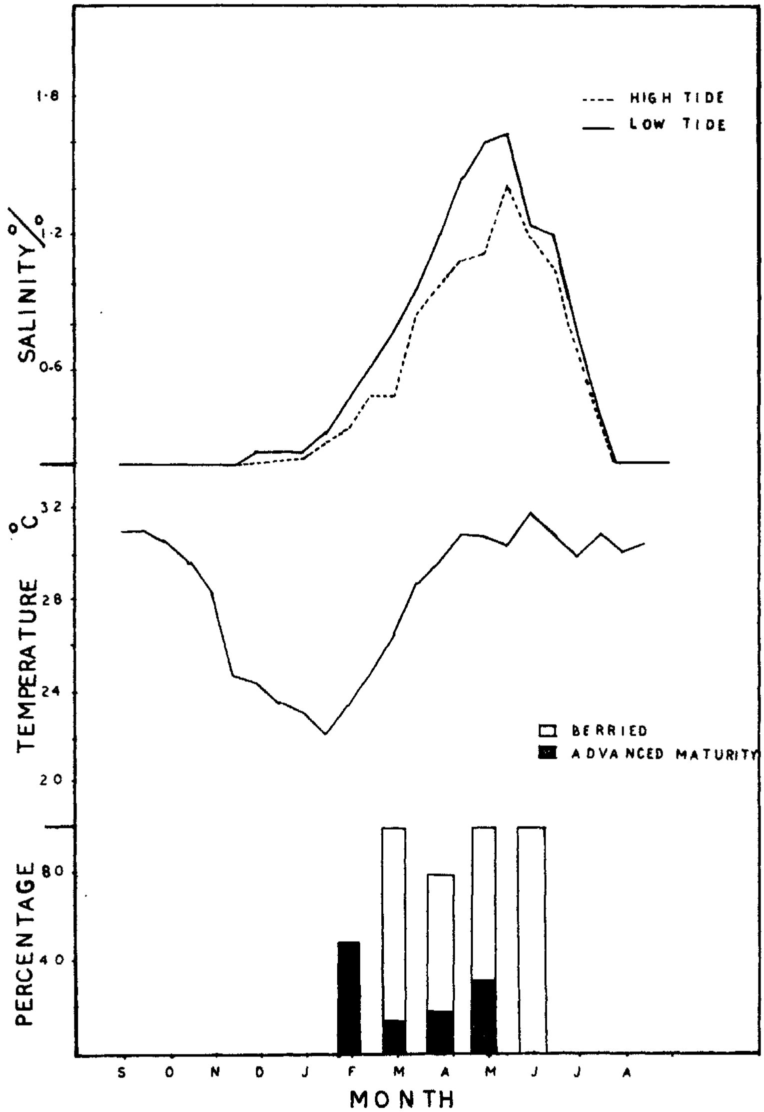


TEXT-FIG. 10. Relationship between total length and maturity in *M. rosenbergii*.

the females and males below 120 mm and 145 mm respectively were immature whereas the percentage of maturity gradually increased with length up to 180 mm in females and 200 mm in males and thereafter all examined specimens were mature. The mean sizes of maturity as indicated by the 50 per cent levels in Fig. 10 were 155 mm and 175 mm for females and males respectively. Rajyalakshmi (1961) recorded the minimum size of maturity for females to be 136 mm.

BREEDING

Rajyalakshmi (1961) reported the spawning grounds of this species to be Fuleswar-Ulubaria region and the peak of breeding season to be March to May (with water conditions during the period being 0·61 per cent to 1·65 per cent salinity and 27·2 to 31·5° C temperature). Percentages of mature females occurring in Ulubaria-Fuleswar region, when plotted for different months along with the hydrological conditions of the river at Fuleswar (Text-fig. 11),



TEXT-FIG. 11. Occurrence of mature females as correlated with the fluctuations in hydrological conditions in the presumptive spawning ground during the years 1955 to 1960.

indicate, in addition to the confirmation of the observation of Rajyalakshmi, that the physiological drive for maturity and spawning migration appears to stem from the rise in temperature and salinity during the breeding season, as compared to the previous months. The post-spawning migration may be due to the decline in salinities to traces during August onwards.

FOOD HABITS

The analysis of food contents has been based on the examination of 396 individuals. The identification of the specific items of food was difficult due particularly to the mandibular action in the mastication which results in the fragmentation of food items. The prevalence of food items was determined by the 'Occurrence Method' (Hynes 1950) where the number of stomachs in which each item is found is expressed as a percentage of number of stomachs examined during the month (Table VII). It seems that the principal items of food, namely debris, sand and crustacean remnants, remain more or less prevalent to the same extent in all the months. Other items of food are molluscan remains, filamentous algae, plant and animal tissues. John (1957) observed that specimens from the paddy-fields had paddy grains in their stomachs. Rao (1965), while working on the breeding behaviour, could administer a variety of food items of both animal and plant origin as relished food and found that the species is cannibalistic and even eats its moult and dead eggs. From this, it can be concluded, as reviewed by Bhimachar (1965), that the animal is a bottom feeder and omnivorous. The condition of feed was high during January to April and in September. The immature specimens were mostly found with empty stomachs, the percentage of full stomachs being 13·93 per cent and 14·91 per cent in females and males respectively. The percentages of full stomachs in mature specimens were 32·97 per cent in females and 55·56 per cent in males. The low value in mature females may probably be due to the presence of enlarged ovary in the carapace restricting the gut from normal feeding before and during the breeding season.

AVAILABILITY OF POST-LARVAE AND JUVENILES

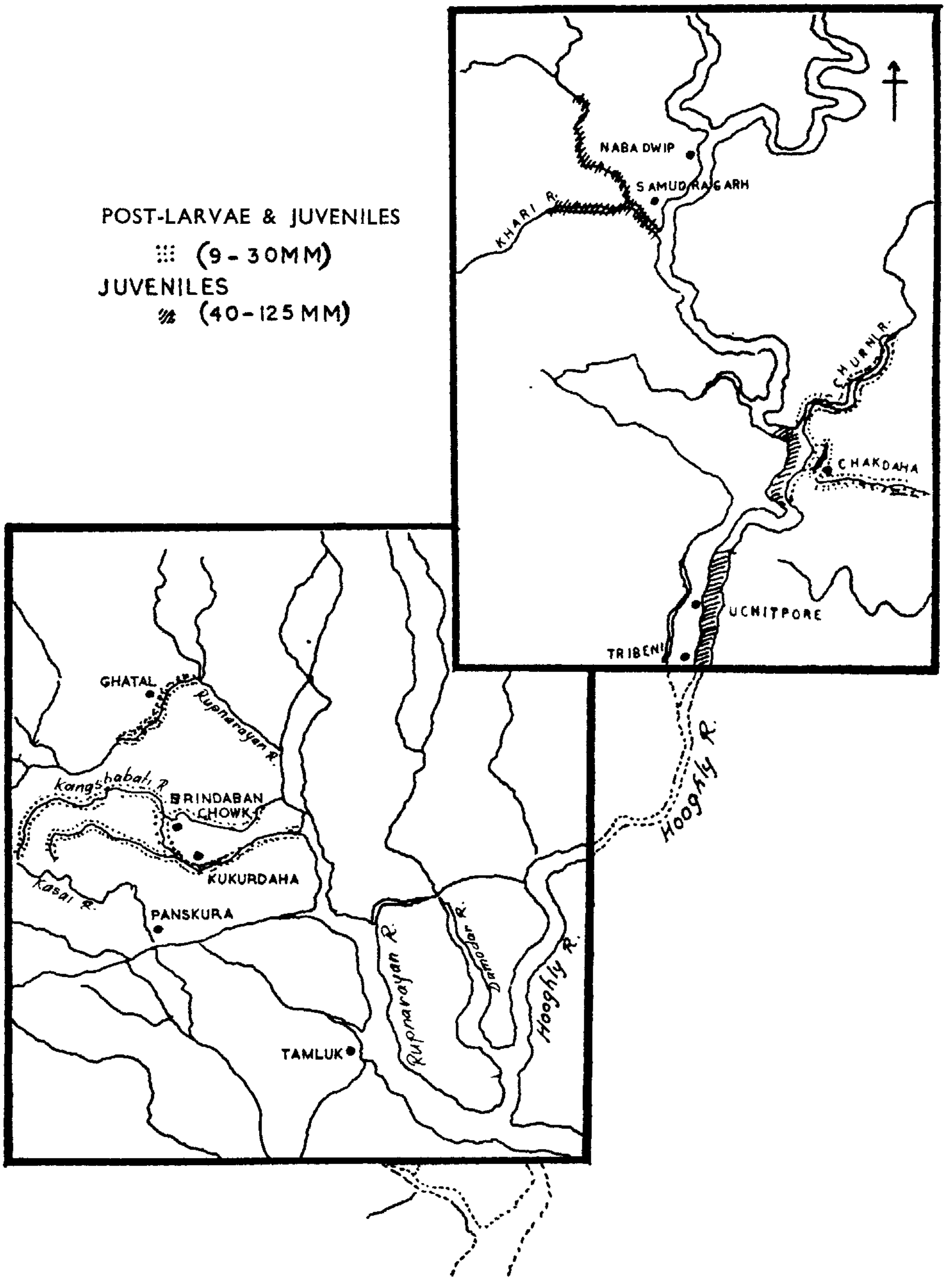
It is of commercial value with reference to the culture of this species to stock the young ones, whose sizes are small enough for easy transportation. Bhimachar (1965) states that 'studies on centres and seasons of availability of larvae and juvenile prawns will make available the seed necessary for cultural purposes' and Pantulu (1965) stresses the need for maximizing the production of prawns through culture. Several centres have been located from a survey conducted by the Central Inland Fisheries Research Institute in different spots of the Hooghly estuarine system and Ichamati river. Text-fig. 12 illustrates the availability of post-larvae and juveniles. Smallest individuals (9 mm to 30 mm in T.L.) are found, during May to July months, ranging from

TABLE VII

Percentage prevalence of various items of food and condition of feed

Sl. No.	Item	Jan. (%)	Feb. (%)	Mar. (%)	Apr. (%)	May (%)	June (%)	July (%)	Aug. (%)	Sept. (%)	Oct. (%)	Nov. (%)	Dec. (%)	All months pooled (%)
1	Debris	26·23	36·21	—	36·67	31·25	—	—	—	33·90	—	33·33	—	32·64
2	Sand	26·23	20·69	—	30·00	18·75	—	—	—	32·20	—	26·67	—	26·36
3	Molluscan remains	1·64	13·79	—	—	—	—	—	—	3·39	—	—	—	4·60
4	Crustacean remains	16·39	5·17	—	6·67	12·50	—	—	—	15·25	—	13·33	—	11·72
5	Filamentous algae	11·47	13·79	—	10·00	—	—	—	—	—	—	—	—	7·53
6	Diatoms	—	—	—	—	—	—	—	—	1·79	—	6·67	—	0·84
7	Fat globules	6·56	—	—	3·33	12·50	—	—	—	—	—	—	—	2·93
8	Plant tissue	10·34	—	—	13·33	—	—	—	—	11·86	—	20·00	—	9·20
9	Fish remains	1·64	—	—	—	6·25	—	—	—	—	—	—	—	0·84
10	Animal tissue	1·64	—	—	—	12·50	—	—	—	1·70	—	—	—	1·67
11	Miscellaneous	4·92	—	—	—	6·25	—	—	—	—	—	—	—	1·67
	Condition of feed	60·0	42·86	—	23·27	12·12	0·0	0·0	0·0	24·39	0·0	9·09	—	

9·3 per cent to 57·0 per cent of prawns in Brindaban Chowk of Roopnarayan and in Chakdaha of Hooghly (Text-fig. 12) during which time salinities were from traces to 0·2 per cent and temperatures 29° C to 31° C. In Samudragarh



TEXT-FIG. 12. Map showing the availability of post-larvae and juveniles of *M. rosenbergii* in the Hooghly and the Roopnarayan estuaries.

at Mirzapur Canal (Text-fig. 12), during September and October months, specimens of length from ranging 40 mm to 70 mm in T.L. are recorded. At Itindaghat on Ichamati river during the same period, about 90 per cent of prawn catches comprise of *M. rosenbergii* of sizes 70 mm to 125 mm in T.L. The post-larvae and the youngest juveniles are found in shallow canals of rivers, of about one metre deep and are fished by local fishermen with fine-meshed cloth and small bagnets of one metre diameter at the mouth and two to three metres' length; the mouth-end being partly exposed above the water level during operation, in very slow currents of water.

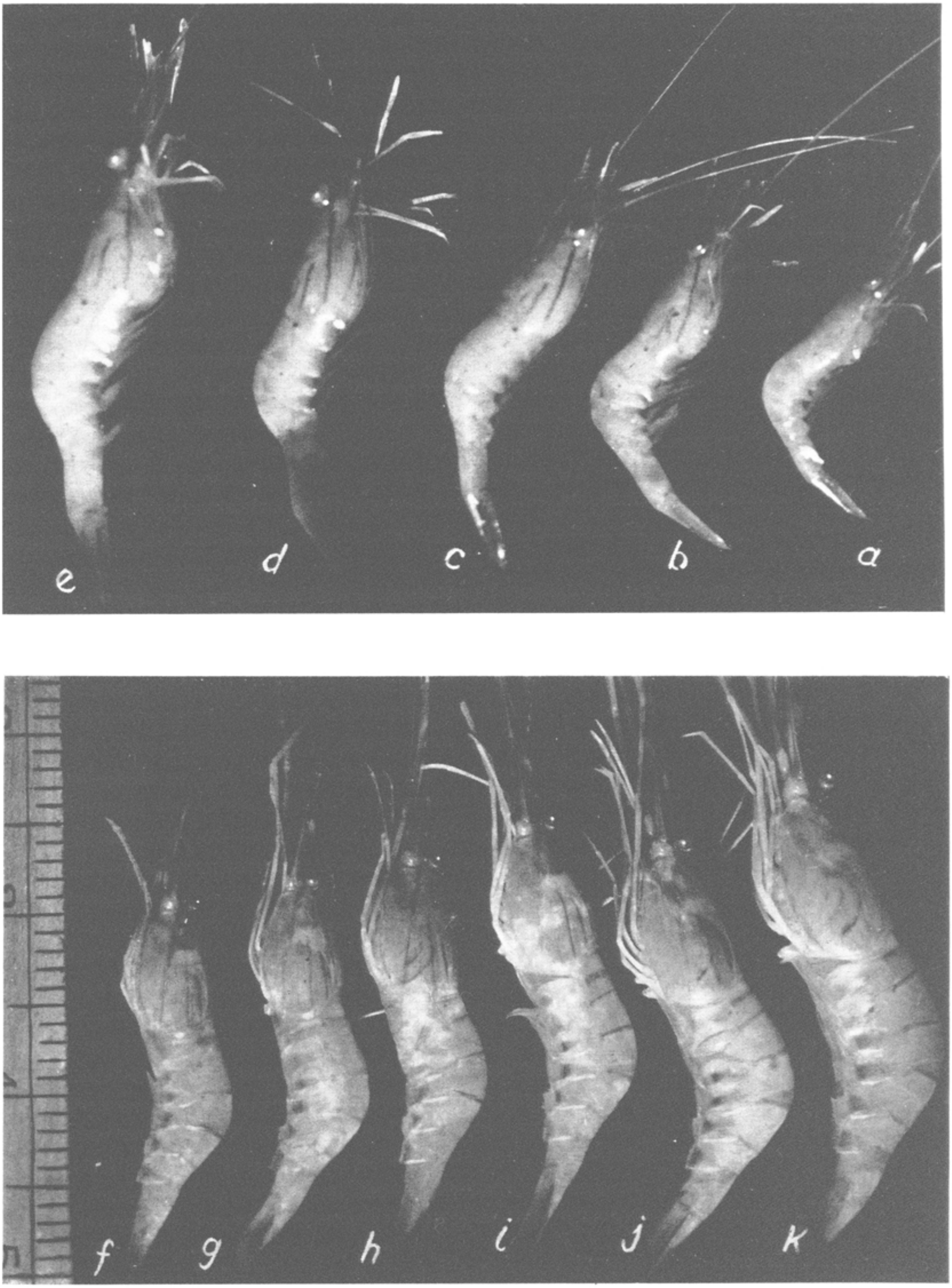
Identification of juveniles:

The various sizes of juveniles from 18 mm to 100 mm show horizontal lines on the carapace characteristic of the species (Plate XII) ranging from one in the smallest to seven or eight lines in the bigger specimens. After about 90 mm the markings disappear, but the junctions at the abdominal segments develop dark abdominal belt-like continuous patches (Plate XIII*a*) which remain throughout the life of the species. Young ones of *M. malcolmsonii* and *M. villosimanus* have also horizontal lines on the carapace but they are discontinuous, being more or less dotted (Plate XIII*b*), and on the lateral sides of their abdominal segments regular dots in rows are also present. *M. rude*, on the other hand, possesses three or four transverse lines on the carapace. Raman (1964) has located the nursery ground of the species in the Vembanad lake area of Kerala. In identifying, he states that juveniles of *M. rosenbergii* can easily be distinguished from those of the other species by the presence of parallel longitudinal lines on the carapace.

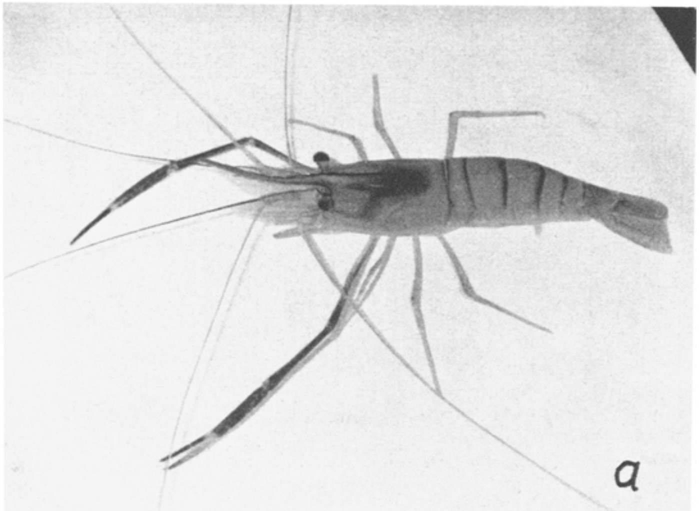
Fishery

M. rosenbergii forms considerable fishery in the freshwater zone of the Hooghly, the Roopnarayan and the Ichamati rivers. To a lesser extent, it contributes in the gradient zone of the Hooghly river. Only stray individuals of 0-year have been recorded in the marine zone of the Hooghly and the Matlah estuaries, though large quantities of bigger specimens of *M. rosenbergii* from *bheries* constitute the fisheries.

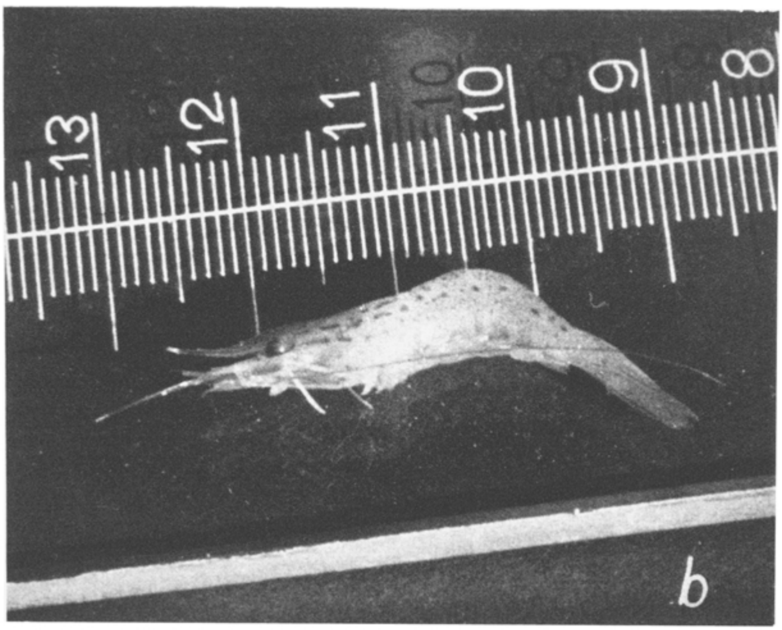
Freshwater zone of the Hooghly river.—The maximum amount of fishery is constituted by I and II year age groups followed by 0, III and other age groups (Text-fig. 2). During the months January to April, the fishery is constituted by all age groups except 0-year individuals, the dominant ages being II and III years. During May and June, the fishery, though less, is mostly of III and IV years. Between the months June and December, the peak period being August to October, 0-year groups are available. July to August months mostly comprise of I year age groups. During September to November, the fishery is mainly of post-spawners consisting of II year and subsequent ages. This period of the year constitutes the peak of the fishing



Juveniles of *M. rosenbergii* of sizes: (*a*) 18 mm, (*b*) 22 mm, (*c*) 24 mm, (*d*) 26 mm, (*e*) 29 mm, (*f*) 74 mm, (*g*) 75 mm, (*h*) 79 mm, (*i*) 83 mm, (*j*) 92 mm and (*k*) 100 mm in total length showing the characteristic horizontal markings on the carapace.



a. Adult of *M. rosenbergii* showing the abdominal patches.



b. Juvenile of size 38 mm in total length of *M. villosimanus* showing discontinuous horizontal lines.

season for this species in the freshwater zone of the Hooghly river. November and December months show an identical composition, but considerably less in abundance. The slack months in the fishing are February and March, June, November and December (Text-figs. 3 and 4).

Gradient zone of the Hooghly river.—The fishery is mostly confined to the Ulubaria-Fuleswar region of the gradient zone of the Hooghly estuarine system during the spawning season initiating from February and lasting up to July, by almost only females in berry and of advanced stages of maturity.

Gear:

Though the species is caught in every kind of net in stray cases, normally they are captured in Traps (*Bithi* and *Duarbithi*), Bush (*Kumor*) and light fishing and cast nets, which are generally meant for prawns in the freshwater zone of the Hooghly estuary.

By and large, operations involving hauling are done during the low tides because of the bottom-feeding habits of the species. Traps are located all along the river in the freshwater zone on the banks from Tribeni onwards (Text-fig. 12). These are kept in the highest high tide and the prawns are taken out during the low tides. Bush fishing is interesting in its operational techniques. Twigs and branches of trees are planted on the banks of the river in a cluster, where water depths are not more than two fathoms, and the leaves are allowed to decay for a fortnight. Then, during the low tides, *Kumor jal*, a drag net of 30 to 40 feet in length with $\frac{1}{2}''$ to $1''$ mesh-size with earthen sinkers, will be encircled around the bush. While the branches are being taken out, the bottom of the net is gradually scooped centripetally and ultimately joined by two or three fishermen and finally the net is hauled to get considerable quantities of prawns. The cast nets, *Khapla*, are generally operated during the low tides in knee-deep waters by fishermen where there are uneven and rough beds.

In the gradient zone of the Hooghly river the species is generally caught in the bag nets, like *Thor* and *Been jals* and cast nets.

SUMMARY

Age and growth of *M. rosenbergii* was studied by Peterson's method as well as by actual rearing. Relationships between T.L. and C.L. and *vice versa* were estimated. Lengths and weights in their logarithmic values were related linearly in the form $\log W = -5{\cdot}52748 + 3{\cdot}19346 \log L$. Relative conditions were calculated for different lengths and for different months, and the probable reasons for the observed fluctuations in relative conditions were discussed. Sex-ratios, calculated for different ages and months, indicated comparative probable mortalities and separate shoaling habits in sexes. An

account of maturity and migratory habits were dealt with in detail. A study of gut contents revealed an omnivorous and bottom-feeding habit of the species. Fishery of this species as well as the availability of seed were discussed.

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