

Ecology of Sandy Beach at Sancoale, Goa : Part II -Population Model & Production of *Emerita holthuisi* Sankolli

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Beach population of *E. holthuisi* was constituted by 0, 1 and 2 yr classes. Individuals were recruited abundantly in June and July. Berried females were of the size range 10 to 15 mm carapace length. Spawning extended from December to June with a peak in March. Annual instantaneous mortality coefficient was high and only a small fraction of the 1 yr class entered the 2 yr. Production was high during the premonsoon months suggesting that stable physical conditions are conducive for production.

MOLE crab, *Emerita holthuisi*, recorded from the sandy beach of Mirya, Ratnagiri¹, forms a major component of the macrofauna inhabiting the sandy beaches of the west coast of India and contributes significantly to the beach production. Apart from its larval development² and some notes on its size-frequency distribution, length-weight relationship and larval recruitment from 2 sandy beaches in south-west India³, no other studies have been made either on the biology or production of this species. Hence, the present work has been undertaken to study these aspects in this species from a sandy beach in Goa where it occurs in abundance.

Materials and Methods

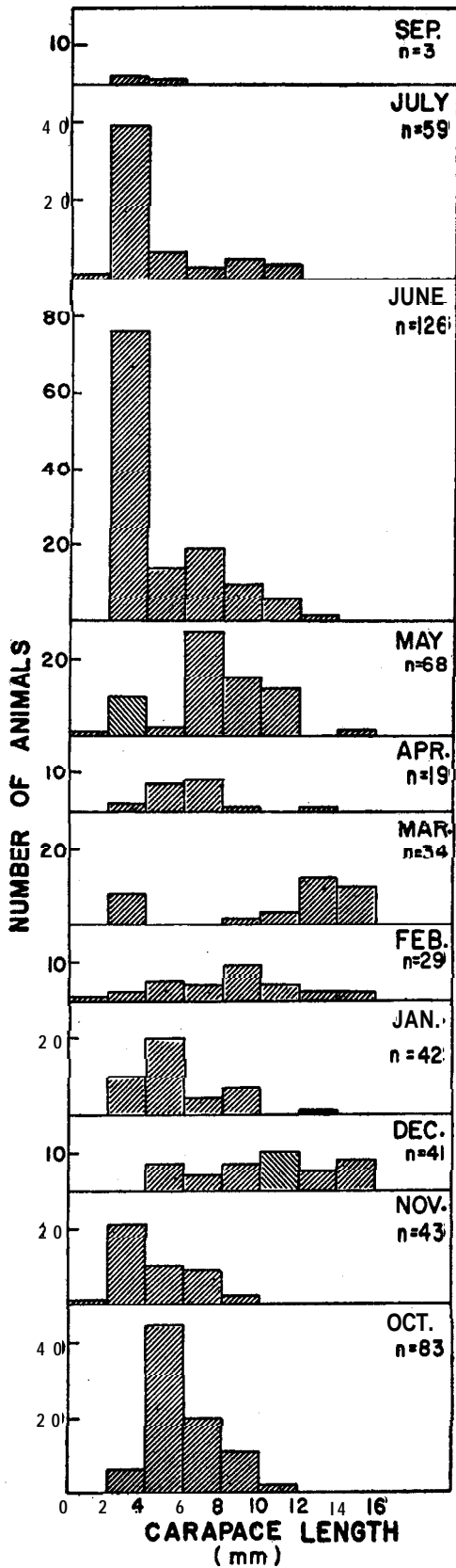
The topography, physical conditions and other related aspects of the area of study are described⁴. Specimens of *E. holthuisi* were collected from a single transect at 5 m intervals from a fixed reference point above the high tide mark to the surf washed zone using a quadrat of 0.1 sq. m area and a 0.5 mm mesh sieve. Collections were made at fortnightly intervals over a period of 12 months (October 1973 to September 1974) covering all 3 seasons, viz. postmonsoon (Oct.-Jan.) — period when the physical conditions of the beach become gradually stabilized after annual monsoon, premonsoon (Feb.-May) — period when the physical conditions remain largely unchanged and monsoon (June-Sept.) — when rainfall severely alters the physical conditions of the beach. Carapace length (mm), wet weight (mg) and the sex of all specimens collected were recorded. Age and growth studies were made by the length-frequency method and probability plot technique. Fecundity estimates were made by counting all the eggs from 9 mature females.

Results

Age and growth — Length frequency distribution of monthly samples collected (Fig. 1) indicates the presence of more than 1 mode except in Oct. '73, Nov. '73 and Sept. '74. The validity of length

frequency distribution in determining the age and growth of tropical fishes has been shown by Qasim⁵. According to him, either slow growth or prolonged breeding or a combination of both will render the tracing of the progress of modes difficult. The fact that the modes in different months (Fig. 1) do not follow a regular pattern indicates the influence of either or both of these factors. Therefore, various modes obtained for different months are arranged (Fig. 2) in order to trace the progress of modes. Moulting or ecdysis, a characteristic phenomenon by which growth in crustaceans is effected is also taken into consideration while tracing the movement of the modes. Immediately after the moulting, there is a rapid increase in the body proportions resulting in a large size which is followed by an inter-moult period during which the hard exoskeleton prevents growth until the next moulting. The 3 mm mode of Nov. '73 is traceable to 5 mm mode in Dec. '73, an increase in length after moulting. This 5 mm mode remains the same until Feb. '74, indicating the inter-moult period, when the next moult leads to an increase in length to 7 mm in April '74. This is followed by a 'no growth' period till June '74, and the next moult increases the length to 9 mm in July '74. Likewise, the 11 mm mode of Dec. '73 is traceable to 15 mm in May '74 through 2 growth periods, 11-13 mm and 13-15 mm with an inter-moult period from January to April '74. The 3 mm mode persisting in May, June and July '74 reflects an inter-moult period which would have led to an increase in size, though the subsequent mode is not represented in the present collection.

Breeding in *E. holthuisi* extends from December to June with a peak in March (see maturity and spawning). On average, it takes 27 days to complete the larval development in *E. holthuisi*, the 6th zoea moulting into a megalopa of approximately 1.7 mm carapace length². Considering the planktonic phase (27 days) and the time that would have been taken by the megalopa (1.7 mm) to grow to 3 mm carapace length, the 3 mm mode of May '74 is probably the result of spawning in the preceding



months (1974 spawning season). Likewise, the 3 mm mode of Nov. '73 comes from the breeding occurring in the preceding months of 1973 spawning season. This 3 mm mode of Nov. '73 progresses to 9 mm mode in July '74 which represents an average growth rate of 0.75 mm/month. Taking this average growth rate into consideration, the 11 mm mode of Dec. '73 can be traced back to the breeding in 1972. Thus, it is evident that the present collection is constituted by 3 yr classes, namely 0, 1 and 2, products respectively from the breeding seasons of 1974, 1973 and 1972. This indicates that though the breeding is prolonged it results in only 1 distinct year class. Cassie's⁶ graphical method of separating age groups in a polymodal length frequency distribution also showed the presence of 0 and 1 yr classes (Fig. 3).

With the growth rate of 0.75 mm/month, as calculated from the progress of modes in 1 yr class, it is evident that the 3 mm sized individuals would have taken 4 months to grow to that size. Further increase in lengths at monthly intervals is obtained from Fig. 2 and summarized in Table 1. These values are utilized in estimating Bertalanffy parameters (L_a , K , t) and in fitting the growth equation.

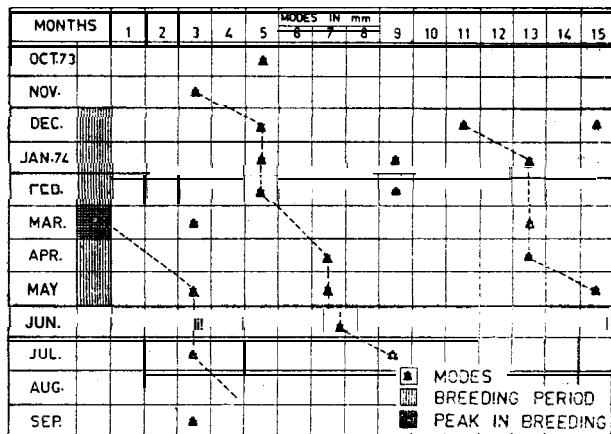


Fig. 2 — Monthwise position of growth modes in *E. holthuisi*

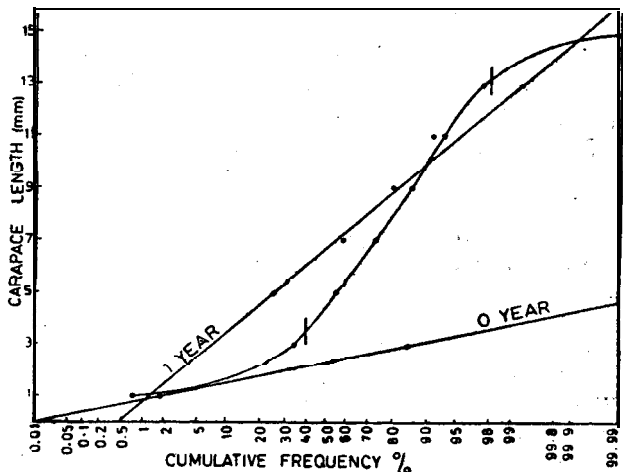


Fig. 3 — Probability plot of the length frequency distribution of *E. holthuisi*

Fig. 1 — Length frequency distribution of *E. holthuisi* in Sancoale beach from October 1973 to September 1974

TABLE 1 — GROWTH IN *E. holthuisi* SANKOLLI

Age (months)	Length frequency (mm)	Bertalanffy equation (mm)	Age (months)	Length frequency (mm)	Bertalanffy equation (mm)
1			11	7	8.91
2	—	—	12	9	9.72
3	—	1.96	13	—	10.34
4	3	3.1	14	11	11.08
5	5	3.83	15	13	11.64
6	5	4.83	16	—	12.19
7	5	5.84	17	13	12.84
8	—	6.61	18	13	13.33
9	7	7.53	19	15	13.69
10	7	8.23			

TABLE 2 — CORRELATION COEFFICIENT (r) AND DEVIATION (t) FROM ISOMETRIC GROWTH IN THE LENGTH-WEIGHT RELATIONSHIP OF *E. holthuisi*

Season	Sex	r	t
Premonsoon	Males	0.9288	1.5095
	Females	0.9897	21.8863*
Monsoon	Males	0.9723	6.1806*
	Females	0.9781	13.1392*
Postmonsoon	Males	0.9493	3.6867*
	Females	0.9690	3.6312*
Premonsoon and monsoon	Females		
	<10 mm length	0.9795	15.3671*
	>10 mm length	0.8784	3.0393*

*Significant at 0.01 level ($t_1\% = 2.58$).

The von Bertalanffy growth model and Walford-plot technique are being widely used to study the growth of various organisms. Bertalanffy's growth equation, based on the concept that growth is the net result of anabolism and katabolism, produces a growth curve in length that explains well the growth rates of many species'. This equation is expressed as

$$l_t = L\alpha[1 - e^{-K(t-t_0)}]$$

where $L\alpha$ is the theoretical average maximum length, K is the growth constant indicating the rate at which length approaches $L\alpha$, l_t is the length at time t and t_0 is the calculated time at which l is equal to zero.

In Ford and Walford method, for lengths obtained at equal time intervals, the length at a given age (l_t) is plotted against the length at the next interval of time (l_{t+1}) and a straight line is fitted by means of least squares. The relationship between l_{t+1} and l_t may be expressed as,

$$l_{t+1} = L\alpha(1 - e^{-K}) + l_t e^{-K}$$

The length at monthly intervals (Table 1) were used in fitting the regression. The point where this straight line intersects the line of equality gave the value of $L\alpha$. K was calculated from the value of the slope (0.957). Thus,

$$L\alpha = 25.5 \text{ mm and } K = 0.044$$

t_0 was calculated by the following equation:

$$t_0 - t = 1/K[\log e(L\alpha - l_t)] - t$$

and was found to be 1.119

Substituting the values of K , $L\alpha$ and t_0 in the Bertalanffy growth equation, growth in *E. holthuisi* may be expressed as

$$l_t = 25.5[1 - e^{-0.0440(t-1.1190)}]$$

Length-weight relationship — All the 507 specimens collected were utilized to study the length-weight relationship of this species. All the specimens were sexed and further subdivided into groups representing the 3 monsoon periods. The exponential equation $W = al^b$ was used to study this relation where W is weight, l is length and a and b are constants. The coefficient of correlation r in all cases was above 0.9 indicating a high degree of relationship between length and weight (Table 2). Weights of females

increased at a faster rate than those of males during premonsoon and monsoon months.

The exponents in all the regressions were tested against the exponent in isometric growth by t test, applying the formula of Snedecor⁸.

$$t = \frac{b - \beta}{S_b}$$

The t values are included in Table 2. In all the cases, except in the males of premonsoon, b was significantly different from 3 suggesting a deviation from isometric growth and that the weights of the crabs increase at a higher rate than the cube of lengths. The deviation was more significant in the females collected during the spawning period (premonsoon and monsoon months). To test whether such a high deviation is brought about by spawning, 2 length-weight regression equations were derived separately for the females below and above 10 mm carapace length (10 mm is the minimum length at maturity in females). The b values in both cases were tested against β and the results (Table 2) are quite surprising in that the deviation from isometric growth is more pronounced in immature females (< 10 mm) than the ovigerous ones (> 10 mm). Though we are not able to explain the reasons for this, the results themselves indicate that there are remarkable variations in the length-weight relationship of males and females and also from season to season.

Maturity and spawning — Microscopic examination of gonads of all specimens collected showed that females of *E. holthuisi* attain maturity at 10 mm carapace length. Egg bearing females were found in the range of 10-15 mm carapace length. To arrive at the spawning periodicity and time, the percentage occurrence of berried females were plotted against respective months (Fig. 4). It is apparent from the figure that there is a single major spawning season, extending from December to June with a peak in March and a supplementary peak in October.

Fecundity — Fecundity estimations were made by enumerating all the eggs from 9 mature specimens representing different size groups. Fecundity

ranges from 102 eggs in a specimen of 12.7 mm carapace length to 2309 in another with a length of 13.9 mm. Individuals above 13.9 mm were found to carry less number of eggs (14.2 mm specimen having 1194 eggs and 15.3 mm with 557 eggs) indicating that they are spawning ones.

Regressions fitted for fecundity with length and weight show that the fecundity bears much better relation to weight than length. The equations are, for length, $\log F = -1.9857 + 4.2923 \log L$ ($r = 0.3684$) and for weight, $\log F = -0.7541 + 1.2918 \log W$ ($r = 0.4927$).

The regression fitted for the ovary weight on length is

$$\log O = 1.2492 + 3.3357 \log L \quad (r = 0.5320)$$

The fecundity increases at almost an equal rate ($b = 4.29$) with the weight of the spawning females to length ($b = 4.5977$ and 4.1234). The ovary weight increases at a rate lower ($b = 3.3357$) than the weight of the spawning females to length.

The regression of fecundity on ovary weight was found to be

$$\log F = 1.5131 + 0.9155 \log O, \quad (r = 0.9643)$$

The exponential value (0.9155) indicates that the fecundity increases at a rate less than the body weight and ovary weight to length.

Recruitment — Individuals are recruited to the beach population when they attain an average carapace length of 3 mm (see, age and growth and Fig. 2). As seen from Fig. 4, the major spawning season extends from December to June with a peak in March and supplementary minor peak in October. As a result of this, individuals are being recruited almost throughout the year. The main period of recruitment is June and July (Fig. 1).

Mortality — Among the several methods available for the estimation of the annual instantaneous mortality coefficient (Z), the simplest is by comparing the abundance at successive ages⁵ when Z is obtained by the following formula:

$$e^{-Z} = S = N_2/N_1$$

where N_1 and N_2 are the number of individuals in the year t and $t+1$ respectively and S is the annual survival rate. Based on this, Z in *E. holthuisi* was calculated by comparing the abundance of 1 yr old specimens with that of 2 yr old ones and was found to be 1.85. As there is no fishing for *E. holthuisi* in Sancoale beach, the total mortality represents only natural mortality due to death by natural causes including predation.

The low annual survival rate (0.1564) indicates that most of the individuals die at the end of 1 yr itself and only a small fraction of the population passes on to the spawning ages as the females were found to attain maturity at 10 mm carapace length (just after 1 yr age).

Production — Achuthankutty⁴ has described in detail the standing crop of *E. holthuisi* at different stations during each observation and the importance of this species in the macrofauna production of the Sancoale beach. The numerical abundance and respective wet weights for each month are given in Fig. 5. The biomass was high during the pre-

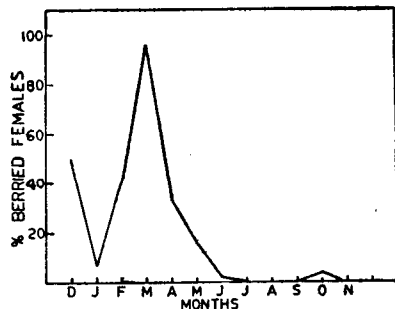


Fig. 4 — Monthwise percentage occurrence of berried females of *E. holthuisi*

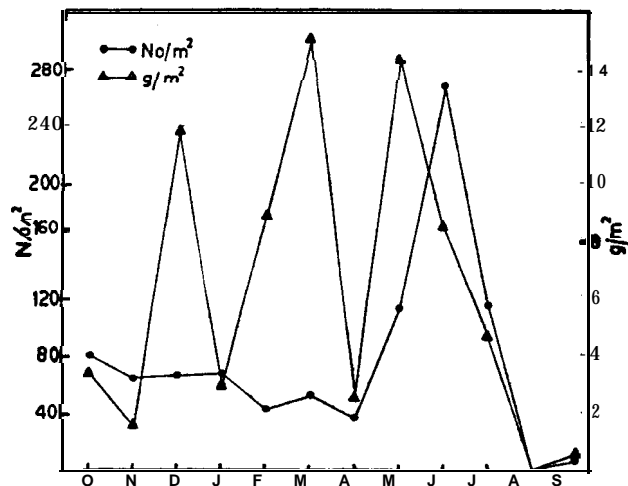


Fig. 5 — Production of *E. holthuisi* in the Sancoale beach

monsoon season when the physical conditions were stable. Due to the presence of berried females in the collection, wet weight was fairly high from December '73 to May '74 (2.5 to 14.3 g/m²) although the abundance was low. The wet weight levels in Fig. 5 are in good agreement with those of Fig. 4 during this period, indicating that the higher biomass was mainly contributed by the berried females. Although the numerical abundance was more in June and July '74 (266 and 112/m² respectively), the wet weights were low (8.35 and 4.59 g/m² respectively) due to the presence of newly recruited individuals.

Discussion

Information on the biology of *E. holthuisi*^{2,3} is very much limited. Some interesting studies have, however, been made on other species of this genus⁹⁻¹⁴. Ansell *et al.*³ have suggested the possibility of continuous breeding within the population of *E. holthuisi* along the Kerala coast, but that recruitment to individual beaches is concentrated at some particular period as observed in Shertallai and Cochin where although there is an year-round settlement, two main periods of recruitment could be seen: in the former, in the premonsoon (Feb.-Mar.) and monsoon periods and in the latter, during premonsoon period only. However, intense recruitment of *E. holthuisi* to the population of Sancoale beach is in June and July, although, as in

Kerala coast, individuals are being recruited in small numbers throughout the year (Fig. 1).

Like most of the other crustaceans, the adult males of *E. holthuisi* are smaller in size than adult females. According to Sankolli¹, adult males and females did not vary much in size, males ranging from 11.5 to 17 mm and berried females from 12.5 to 18 mm. In Sancoale, adult males seldom attained a carapace length of 10 mm or above whereas all the ovigerous females were between 10 and 15 mm, the largest being 15.3 mm. This clearly indicates that there is considerable size difference in the adult male and female of *E. holthuisi* and that the individuals of Sancoale beach attain maturity at a smaller size. Having been recruited to the beach population at 3 mm carapace length, the individuals take about 9 months to grow to the adult size. This almost agrees with the observation of Ansell *et al.*³ in south-west Indian beaches, where they grow to the adult size of 12 mm in 8 or 9 months which again confirms the fact that the crabs of Sancoale beach attain maturity at a smaller size.

Ansell *et al.*³ have found that crabs settled during monsoon weighed less for any given carapace length than those of the premonsoon settlement. The data from Sancoale beach showed no weight reduction in the specimens of the monsoon season but the weights of the females increased at a faster rate than those of males of premonsoon and monsoon months.

Spawning periodicity or fecundity studies have not been made for *E. holthuisi* of the south-west Indian Beaches. However, spawning in *E. analoga*¹⁴ begins in late spring and early summer and most of the females are found to be ovigerous as the summer progresses. Similarly, spawning in *E. holthuisi* begins by December and reaches the peak in March when the temperature is high and other physical conditions are stable. Sankolli² has also observed berried females from late September to early June and is of the opinion that this species may be breeding throughout the year except for the rainy season. This is nearly in conformity with the present observation.

Gradual disappearance of males of *E. analoga* during the summer months has been attributed by Efford¹¹ to their death after mating in their 2nd yr. But, Barnes and Wenner¹⁴ have suggested that their disappearance may also be consequence of sex-reversal (protandric hermaphroditism). Sex-reversal may hold good in *E. holthuisi* also since adult males seldom attained a carapace length of 10 mm whereas all the mature females were in the range of 10-15 mm. Further evidence is essential to confirm this.

Reberrying in *E. analoga* has been reported by Boolootian *et al.*⁹ Barnes and Wenner¹⁴ are of the opinion that if reberrying occurs in the field, some females may even reberry for 4 times in a season. Reberrying does not exist in *E. holthuisi* of Sancoale beach because individuals do not complete their 2nd yr of life as the maximum size of the ovigerous females collected was only 15.3 mm. Although the theoretical maximum carapace length attainable by this species is 25.5 mm it never grows to that length in this beach and instead dies at an early age.

The causes and details about mortality occurring at different stages of the life history of *E. holthuisi* from other west Indian beaches are lacking. The low annual survival rate indicates that most of the individuals die at the end of 1st yr of life due to natural causes, especially the unfavourable physical conditions of the monsoon season.

At present, there is no fishing for *E. holthuisi* in Sancoale beach. It is suggested that if this species is to be fished for human consumption or as bait, which is a regular phenomenon in nearby beaches, the suitable period is the late postmonsoon and the premonsoon seasons when most of the individuals attain the adult size. But since this is also the spawning period, over exploitation may adversely affect the subsequent population.

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