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Population selection strategies in the wedge clam, *Donax incarnatus* (Gmelin) from Panambur beach, Mangalore*

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Correlates of *r*- and *K*-selection strategies were examined in an intertidal population of *D. incarnatus*. Settlement extended from November to May. Zero year class dominated the population. Instantaneous total mortality ranged from 0.1824 (January 1985) to 0.3963 (March 1984). Growth rate showed variability, being faster (3.22 mm per month) during the first 6 months than during the rest of the year (1.77 to 0.3 mm per month). L_{max} was 26.1 mm. The von Bertalanffy equation for length was $L_t = 30.94\,[1 - e^{-0.1612\,(t\,+\,0.04)}]$. A life table of a cohort of 1000 individuals was prepared. The life span was < 15 months. Survivorship curve belonged to type Ia of Deevey [*Quart Rev Biol*, 22 (1947) 283]. Selection attributes indicated that this species is a *K*-strategist in this study area.

The wedge clams, of genus *Donax*, form a dominant component in the infauna of sandy beaches of Indian coasts. Though not commercially very important, these clams support small fisheries along certain regions of the east and west coasts of India. Some aspects of the population biology of *Donax* spp have been reported by earlier workers[1-5]. In this paper details of population selection strategies in the wedge clam *Donax incarnatus* (Gmelin) inhabiting the Panambur beach near Mangalore are reported.

Materials and Methods

Samples of *D. incarnatus* were collected monthly (March 1984 - February 1985) using randomly placed quadrants (1 m^2, area up to a depth of 10 cm) at Panambur beach (12°27'N; 74°48'E) near Mangalore, west coast of India. Clams were separated by sieveing the sand (mesh size 1 mm). Lengths (greatest antero-posterior distance) of clams were measured and data grouped into 2 mm size groups. Data on the percentage frequencies of such groups were subjected to analysis by Pauly's integrated method[6] and growth rates determined. Population age structure was determined by considering the mean size attained at the end of 12 months' growth from the above analysis and assigning individual clams to respective year classes. Growth parameters ($L\infty$, K and t_o) were estimated[7] and the von Bertalanffy growth curve[8] $L_t = L\infty\,[1 - e^{-K(t-t_o)}]$ fitted. The instantaneous mortality rate was estimated based on mean size in the sample[9]. A life table and a survivorship curve of a cohort of 1000 individuals were prepared. Life span for the population was estimated[10].

Results and Discussion

Settlement and growth—Cohort analysis: Analysis of the size frequency data by Pauly's integrated method (Fig. 1) shows that recruitment of young clams to the population takes place in several stages as shown by the occurrence of young clams of size < 4 mm in January, May and November indicating a prolonged/staggered breeding period for the population. During July and October progression of modes with time was not marked, indicating cessation of growth during this period. Freshly settled spat shows a faster rate of growth during the first 6 months whereafter it slows down.

Juvenile and adult growth : Differential growth rate and ranges in the size of 0 and 1 y old clams (Fig. 2) show that, growth rate of juvenile clams was high during the first few months after settlement. The growth rates were 5.19, 4.06, 3.00, 2.48, 2.59 and 2.01 mm during the 1st - 6th month respectively. Beyond the 6th month growth was poor and fluctuated between 1.71 mm during the 7th to 0.3 mm during the 13th month.

Growth parameters : The theoretical growth calculated from the L_t data is presented in Fig. 3. The von Bertalanffy growth equation for *D. incarnatus* was

$$L_t = 30.94\,[1 - e^{-0.1612\,(t\,+\,0.04)}]$$

*Forms part of M.F.Sc thesis of S.T.

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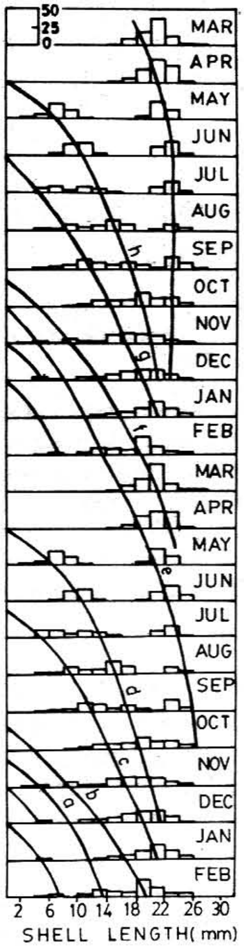

Fig. 1—Population growth as revealed by the analysis of the length-frequency data by the integrated method

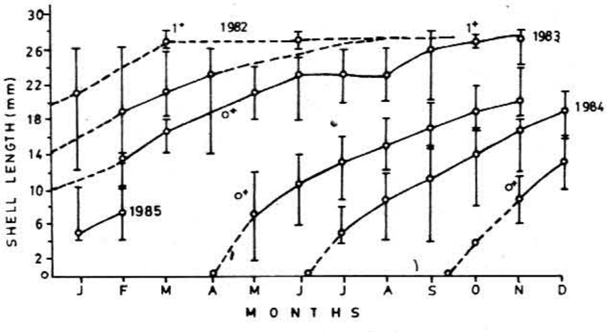

Fig. 2—Differential growth rates of 0^+ and 1^+ age groups of *Donax incarnatus*. Range in the shell length (vertical bars), and extrapolated values (dotted lines)

Table 1 presents data on the maximum theoretical length an organism can attain under given rate of growth (L_∞), average rate at which the sizes of animals approaches the theoretical maximum (K) and maximum size recorded (L_{max}) of *Donax* spp reported from India and elsewhere. Of the 3 parameters of von Bertalanffy, the theoretical time when an organism has zero length (t_0) is only of

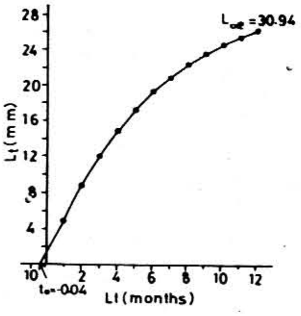

Fig. 3—von Bertalanffy growth curve for *Donax incarnatus* inhabiting the Panambur beach

Table 1—Comparison of von Bertalanffy parameters

Species/year	Locality	K	L_∞ (mm)	L_{max} (mm)
Donax cuneatus				
February 1952 - June 1953	Mandapam[1]	0.0582*	22.8722*	19.30
December 1972 - November 1973	Ratnagiri[4]	0.0429*	33.0193*	22.00
D. incarnatus				
January 1968 - July 1968	Cochin[3]	0.0906*	25.1296*	22.30
January 1968 - December 1968	Shartalli[3]	0.0864*	29.0366*	27.60
July 1973 - June 1974	Goa[5]	0.0874*	20.0591*	19.40
D. faba				
July 1962 - June 1964	Mandapam[2]	0.1006*	26.1452*	24.20
D. trunculus				
1969	Vertbois[12]	0.452	43.48	—
1970	,,	0.704	36.33	—
1971	,,	0.785	35.55	—
1972	,,	0.678	32.25	—
1973	,,	0.701	38.22	—
1969	St. Trojan[12]	0.715	38.41	—
1970	,,	0.740	39.78	—
1971	,,	0.772	39.70	—
D. vittatus				
1971	Vertbois[12]	1.061	31.28	—
1969	St. Trojan[12]	0.612	33.15	—
1970	,,	1.321	29.76	—
1971	,,	1.005	35.90	—
D. incarnatus				
March 1984 - February 1985	Panambur (present study)	0.1612	30.94	26.10

* = values calculated on monthly basis from raw data reported by the authors

theoretical interest which in the present study was −0.04 month. The calculated L_{∞} (30.94 mm) appears to be a realistic estimate in view of the fact that L_{max} for *D. incarnatus* from the Panambur coast was 26.1 mm, which is near to that of *D. incarnatus*[3] from Indian waters (Table 1).

The coefficient K, the rate at which the animal's size approaches the theoretical maximum, can be used to compare between growth of related species or some species in varied habitats. The present estimate (K = 0.1612) is high as against the growth rates of *D. cuneatus*[1,4], *D. incarnatus*[3,11] and *D. faba*[2]; and low as against *D. trunculus*[12] and *D. vittatus*[12]. Because, K denotes the rate at which the growth decreases to reach the maximum, lower values of K denote faster rates of growth. K can be used as an index of the intrinsic development rate of a species and has importance in intra-and inter-specific comparison of growth[13,14].

Population age structure—The mean size at the end of 13 months' growth was 27.2 mm (Fig. 1). The size range of clams in the population was 3.3 to 26.1 mm. Thus it appears that the population comprises individuals of 0^+ and 1^+ y class. Fig. 4 presents the size distribution of population during March 1984 - February 1985. During this period, *D. incarnatus* from earlier settlement in 1982, 1983, 1984 and 1985 (Fig. 2) were present in the samples. This was perhaps related to the extended spawning period (November to May) in the same habitat[15].

Mortality—Total mortality rates (Z) based on the mean size in the sample for whole population ranged from 0.1368 (January 1985) to 0.3963 (March 1984). Mortality rates were higher during the monsoon (June, July, August) and premonsoon (March, April; Table 2). This is probably due to high sediment temperature during premonsoon. At the same habitat high sediment temperature (36°C) was recorded[15] in May 1984. High mortality rate during the monsoon season was probably related to the reduced salinity (30.2 - 33.3 × 10^{-3}) and instability (coarse sand, 1.1 - 4.7%; medium sand, 2.2 - 9.1%; fine sand, 86.1 - 92.1%; very fine sand, 0.4 - 2.3%; silt and clay, 0.02 - 0.05%) of the sandy beach[15].

The cohort size (Fig. 5) was reduced by 50% within 2 months after settlement. The mortality thereafter decreased till the 7th month and subsequently increased till loss of stock. These observations indicate that the mortality of this population was very high during the early stages of life probably due to overcrowding coupled with adverse environmental factors, while during the later stages of life, mortality could be attributed to short life span and predation.

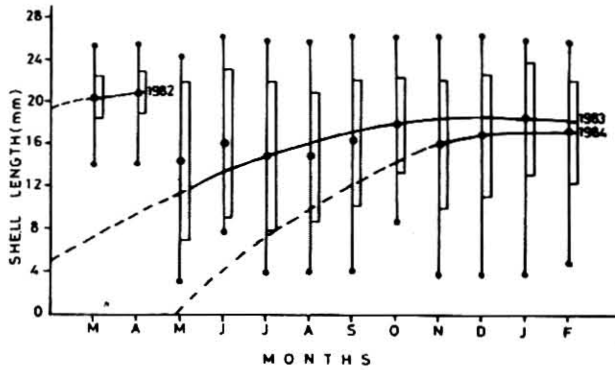

Fig. 4—Seasonal size distribution of *Donax incarnatus*. Overall size ranges (vertical lines), mean sizes (points), standard deviation (histograms) and extrapolated values (dotted lines)

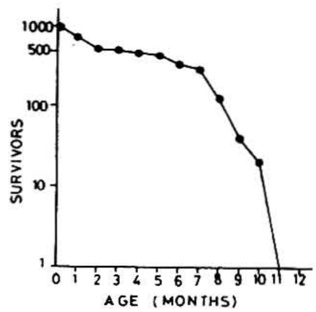

Fig. 5—Survivorship curve for a cohort of 1000 individuals of *Donax incarnatus* settled in 1984. Survivorship curve begins 2-3 months after settlement

Table 2—Seasonal variability in instantaneous total mortality (Z), maximal life span (T) and survival level (λ) of *D. incarnatus*

Month	Z	T	λ
March 1984	0.3963	10.2379	0.8080
April	0.2464	10.2379	0.8080
May	0.1916	9.0964	0.7992
June	0.2797	11.5083	0.8436
July	0.2394	11.0157	0.8306
Aug.	0.2697	10.6770	0.8209
Sept.	0.1945	11.5083	0.8436
Oct.	0.2310	11.1352	0.8339
Nov.	0.1931	11.3814	0.8403
Dec.	0.1775	11.5083	0.8436
Jan. 1985	0.1368	10.8984	0.8274
Feb.	0.1824	10.7833	0.8242

Life span—Maximal size (L_{max}) of this population was 26.1 mm which was reached when the clams were 12 months old. Data on the temporal changes in the values of life span at the sampling site are presented in Table 2. The maximum life span recorded was 11.5 months. According to Table 3 the cohort live for 10-11 months. Thus, based on the available data, and taking into consideration the loss of data during the

Table 3—The life table for a cohort of 1000 individuals of the wedge clam *D. incarnatus* (Life table begins 2-3 months after settlement)

x	l_x	d_x	q_x	L_x	T_x	e_x
0	1000	240	0.2400	880	4018	4.018
1	760	240	0.3158	640	3138	3.997
2	520	4	0.0008	518	2498	4.804
3	516	42	0.0814	495	1980	3.837
4	474	44	0.0928	452	1485	3.133
5	430	86	0.2000	387	1033	2.402
6	344	50	0.1453	319	646	1.878
7	294	174	0.5918	207	327	1.112
8	120	80	0.6667	80	120	1.000
9	40	20	0.5000	30	40	1.000
10	20	20	1.0000	10	10	0.500
11	0	Nil	Nil	Nil	Nil	Nil

x = age (month)
l_x = number of survivors at the start of age interval
d_x = number dying during the age interval x to x+1
q_x = rate of mortality during the age interval x to x+1
L_x = average number of individuals alive during the age interval x to x+1
T_x = number of individual time units left in the population at the start of age interval x
e_x = mean expectation of life for an organism at the start of age interval x

first 2-3 months (Table 3), it is concluded that the life span of this species is about 13-14 months at the present study area.

Survivorship—Temporal variations in survival level λ for the whole population based on L_{max} and $L\infty$ are presented in Table 2. The data suggest a near constant survival level. Survivorship curve of *D. incarnatus* (Fig. 5) illustrates the low survivor level in the juveniles and old age classes. In the early part of life, the curve is very sharp indicating heavy loss of juvenile clams probably due to overcrowding, high or low temperatures and instability of the sandy beach. After the 2nd month, the number of survivors are more till the 7th month whereafter the mortality acts, thus reducing the number of survivors in the subsequent months. In the 11th month clams were completely absent indicating the complete loss of stock.

When the complete record of a species population is considered, including all larval, juvenile and adult stages, the shape of the survivorship curve is sigmoidal, with high mortality in both young and old age classes. The present observations agree well with the hypothetical survivorship curve of type Ia of Deevey[16] and sigmoidal type of Kurton[17] as well as the sigmoidal survivorship curve of California Pismo clam, *Tivela stultorum*[18]. The present sigmoidal survivorship curve represents heavy mortality in juvenile and old classes.

Table 4—Some biological attributes of *K*-selection of *D. incarnatus*

Attributes	*K*-selection
Environment	Failry constant
Population size	Fairly constant in time
Population age structure	Dominated by 0^+ year class
Survivorship	Type Ia[16], Sigmoidal form[17]
Mortality	High in juvenile and old age classes
Life span	Not less than one year (13-14 mon)
Leads to	Efficiency
Stage in succession	Late

Adaptiveness—Two opposing selective forces in a population are denoted by the selection strategies *r*-selection and *K*-selection[19]. Table 4 presents some correlates of population selection strategies of *D. incarnatus*. This population is characterised by low growth rate, high mortalities in juvenile and old age classes, life span more than a year (13-14 mon) and fairly constant population in time. Therefore, *D. incarnatus* inhabiting the intertidal region at Panambur is an equilibrium population.

Correlates of *r*- and *K*-strategies represent opposite ends of a continuous spectrum that runs from unstable or unpredictable changing environments dominated by opportunists to stable or relatively constant environments dominated by equilibrium species[20-23]. Most species will lie somewhere between these two extremes[22,24]. No organism is completely *r*-selected or completely *K*-selected, rather all must reach some compromise between the 2 extremes[22]. The present conclusions are based on the field and quantitative aspects of the population ecology of *D. incarnatus*. However, for a precise grouping of this population as a *K*-strategist, biological data on development, recruitment and intra- and inter-specific competition with respect to time are warranted.

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