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Density, biomass, growth, age, mortality and exploitation of wedge clam, *Donax incarnatus* (Gmelin) from Karnataka coast, India

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The size-frequency distribution method was used to study the rate of growth of Wedge clams of the genus *Donax* (Family: Donacidae). It was found that the clam grew up to 18.1, 24.0 and 26.2 mm at the 6th, 12th and 15th months respectively. The life span of this was less than 2 years. Recruitment pattern was continuous with one major peak in February and March. The minimum and maximum densities of clams were 22 (July) and 1885 ind.m^{-2} (December) respectively. Minimum and maximum values were 1.142 (July) and 193.612 (November) g.m^{-2} respectively. Values of von Bertalanffy growth parameters (L_∞ = 28.35, K = 1.70, t_o = - 0.099) were estimated. The von Bertalanffy growth equation was $L_t = 28.35\ [1\text{-}e^{-1.7(t+0.099)}]$. Total mortality ($Z$), natural mortality ($M$) and fishing mortality (F) rates were 5.18 yr^{-1}, 2.61 yr^{-1} and 2.57 yr^{-1} respectively. Exploitation level (E) of *D. incarnatus* was estimated at 0.50.

[Key words: Age; Growth parameters, mortality, sandy beach, Karnataka]

Introduction

Wedge clam, *Donax incarnatus* is a common inhabitant of sandy beaches in India, living buried in sandy substrates[1]. The intertidal sandy shores are alternately exposed and submerged by tides and inhabited by intertidal organisms and are relatively smaller in size. Although beach ecosystems typically support a low diversity and density of macroinvertebrates, *D. incarnatus* have been recorded in aggregations exceeding several thousand individuals per square meter[2]. Donacids of the family Donacidae are common in the intertidal and subtidal regions in both tropical and temperate regions of the world. Thippeswamy[2] observed *D. incarnatus* occurs in dense populations during breeding seasons in Panambur beach (Karnataka). The wedge clam *D. incarnatus* is one of the dominant organisms on sandy shores of the west coast of the India and is found in Kerala[3], Karnataka[2] and Goa coasts[4,5]. Population dynamics of *D. incarnatus* inhabiting the west coast has been studied by Ansell *et al*.[6] from Kerala, Thippeswamy and Joseph[1] from Karnataka, McLusky *et al.*[4] and Nair *et al*.[5] from Goa. Recently population dynamics of the Indian largest sized wedge clam, *D. scortum* was studied from Padukere nearby Malpe[7]. But the study of population dynamics of the wedge clam, *D. incarnatus* (Gmelin) inhabiting Malpe beach near Udupi, a tourist place, is not available.

Materials and Methods

Malpe is an important fishing port of Karnataka and is about 6 km from Udupi, a main pilgrim center. The study area is located just opposite to a group of 4 small islands collectively known as St Mary's Islands spread over a distance of 4 km from north to south parallel to the mainland of Udupi. The coastal town of Udupi is a seasonal tourist centre where people arrive for mostly recreational purpose. Tourists regularly visit the northern most island, *i.e.* Coconut island from Malpe beach[8]. Therefore, clam beds are affected by tourists and other anthropogenic activities. Due to tourists' related activities, wedge clams are not stable to survive at their habitat (sampling site) and several clams are dead every day. Samples of wedge clam, *D. incarnatus* (Gmelin) were collected at monthly intervals for a period of 1 year from December 2004 to November 2005 from the intertidal sandy beach at Malpe (31º 21'N; 74º 41'E) using randomly placed quadrants (1 m^2, area up to a depth of 10 cm). The sand was sieved with 1 mm screen and all animals were removed and counted, and total weight was recorded. 2394 individuals were individually measured with Vernier calipers to the nearest 0.01 mm to know the shell length. The wedge clams were grouped into size group and subjected to length frequency analysis. FiSAT software package[9] was

used to analyze the growth. Growth curve[10] was drawn using the growth equation $L_t = L_\infty [1\text{-}e^{-K(t- to)}]$ where L_t is the length at time t, L_∞ is the asymptotic length, e the base of the natural logarithm, K the growth coefficient, t the time of observation and t_o the age at which the clams belong to zero size. Estimates of L_∞ and K were used to estimate the growth performance index (ϕ')[11]. Parameter t_o of the growth equation was estimated using the equation given by Pauly[12]. Total mortality (Z) was estimated by length converted catch curve method[13]. Natural mortality rate (M) was estimated using the empirical relationship of Pauly[14] and fishing mortality (F) was estimated by $F = Z\text{-}M$. The mean annual habitat temperature (°C) of seawater was calculated to generate

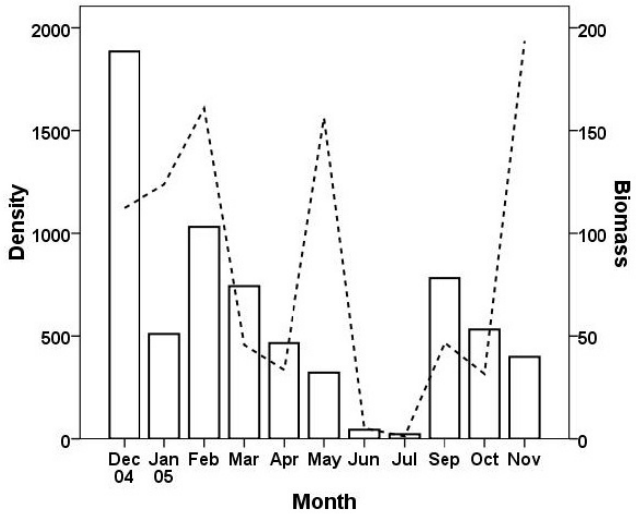

Fig. 1 — Temporal variation in the population density of *D. incarnatus* during the study period

Results

Data on temporal variations of population density and biomass are presented in Fig. 1. In the present study, the maximum density of clams was recorded during December followed by February and September. Minimum and maximum densities of wedge clams were 22 (July) and 1885 ind.m^{-2} (December) respectively. In the case of biomass, the minimum and maximum values were 1.142 (July) and 193.612 (November) g.m^{-2} respectively. Average density was 561 ind.m^{-2}, whereas the average biomass was 75.886 g.m^{-2}. Density of mussels was high during settlement period. Biomass was less when large number of young clams settled. On the other hand, it was high when large sized clams were recorded.

The monthly length-frequency distribution with growth curves superimposed using ELEFAN I is presented in Fig. 2. Asymptotic length (L_∞) of von Bertalanffy growth function (*VBGF*) was 28.35 mm and the estimated value of growth coefficient was (K) was 1.7 yr^{-1}. The observed maximum length was 27.00 mm and the predicted maximum length was 29.32 mm (Fig. 3). The confidence interval was 25.58–33.06 mm (95% probability of occurrence). Growth performance index (ϕ) was 3.14 (Fig. 4).

class, whereas the minimum size was in 2-4 mm class interval. Average size of clams was 11.03 mm. The wedge clams attained the size of 18.1, 24.0 and

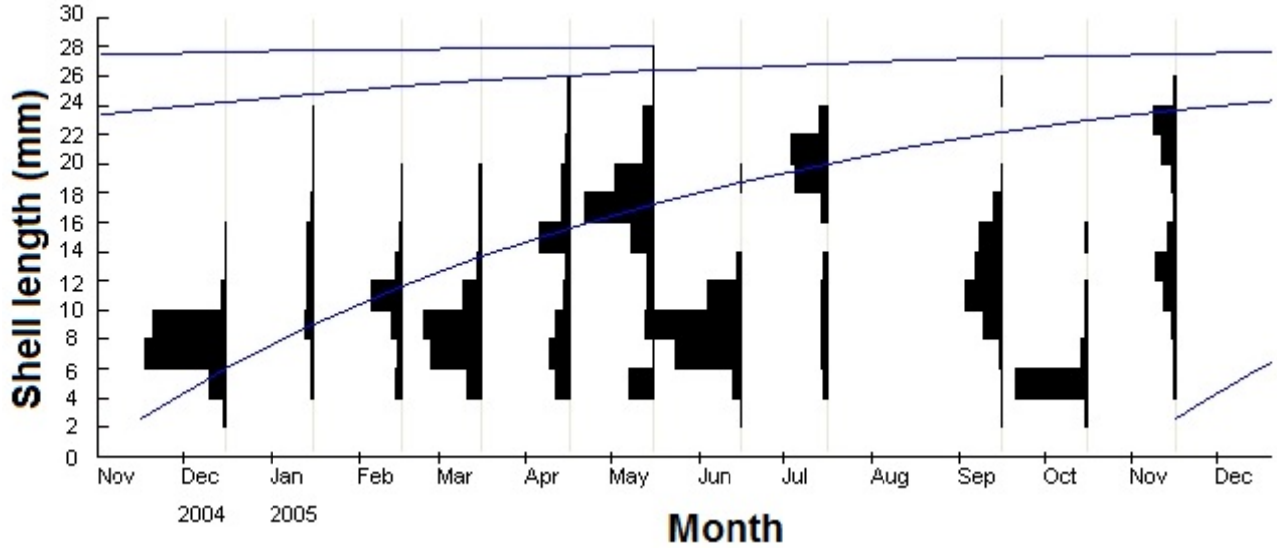

Fig. 2 — Growth curves of *D. incarnatus* as superimposed on the length-frequency histogramsdata. Recruitment pattern was obtained by projecting the length-frequency data backwards on the time axis using growth parameters[15].

26.2 mm at the 6th, 12th and 15th months respectively. Life span of *D. incarnatus* in the present study is about 2 years (1.5 years, *i.e.* less than 2 years). Calculated average growth rates of *D. incarnatus* for the 6th, 12th and 15th months were 13.33, 0.98 and 0.44 mm respectively. The von Bertalanffy growth equation for the *D. incarnatus* was $L_t = 28.35\ [1\text{-}e^{-1.7(t+0.099)}]$. The von Bertalanffy growth curve is presented in Fig. 5.

Estimations of all different mortalities are presented in Fig. 6. Total mortality (Z) of *D. incarnatus* based on the length converted catch curve was 5.18 yr^{-1}. Estimated natural mortality (M) and fishing mortality (F) of wedge clams were 2.61 yr^{-1} and 2.57 yr^{-1} respectively based on the mean habitat temperature (29°C). The exploitation level (E) of *D. incarnatus* was 0.50 (Fig. 6).

The recruitment pattern of *D. incarnatus* was continuous throughout the year, with one major peak observed was during January-February (Fig. 7). Percent recruitment varied from 0.53 to 19.91 during the entire period. Highest and lowest percent recruitment was observed in February and November respectively.

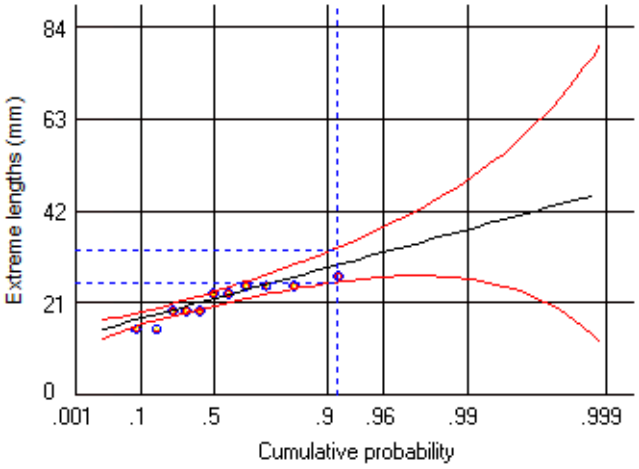

Fig. 3 — Estimation of maximum length of *D. incarnates*

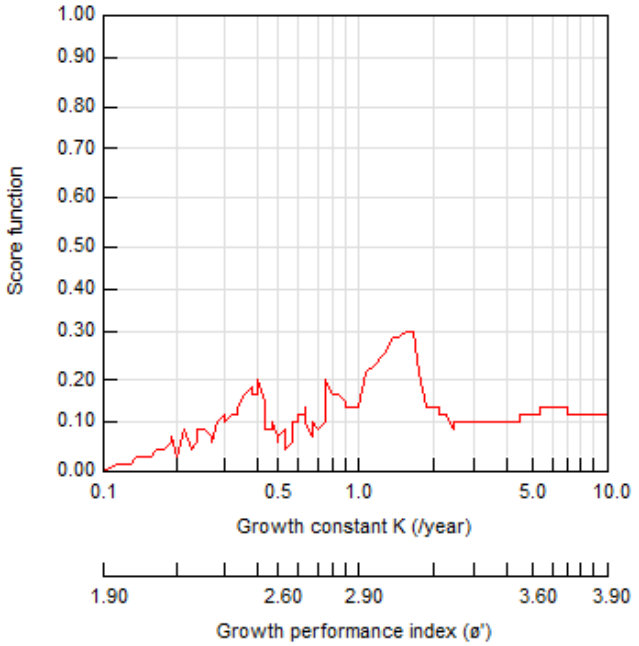

Fig. 4 — Estimation of maximum length of *D. incarnatus*

Discussion

The considerable changes take place in the beach profile due to accretion and erosion during monsoon

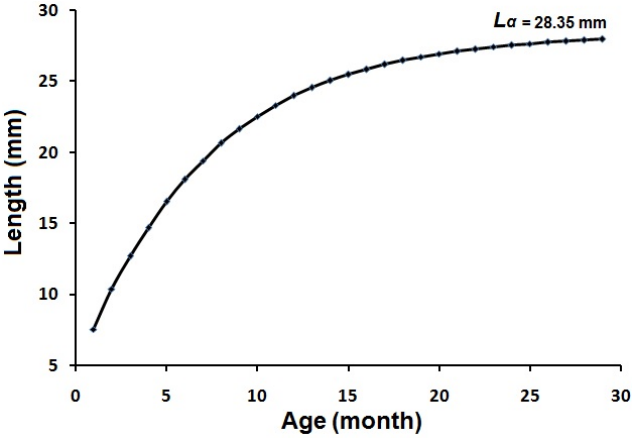

Fig. 5 — von Bertalanffy growth curve for the length of *D. incarnatus* inhabiting Malpe beach

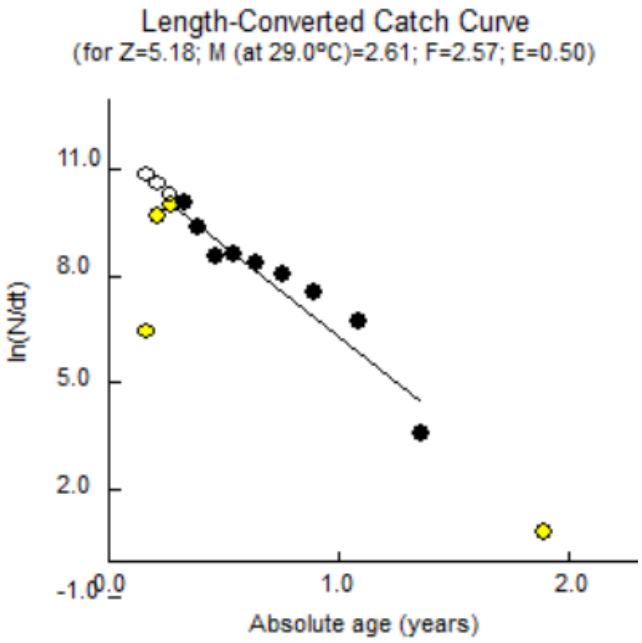

Fig. 6 — Length converted catch curve of *D. incarnatus*

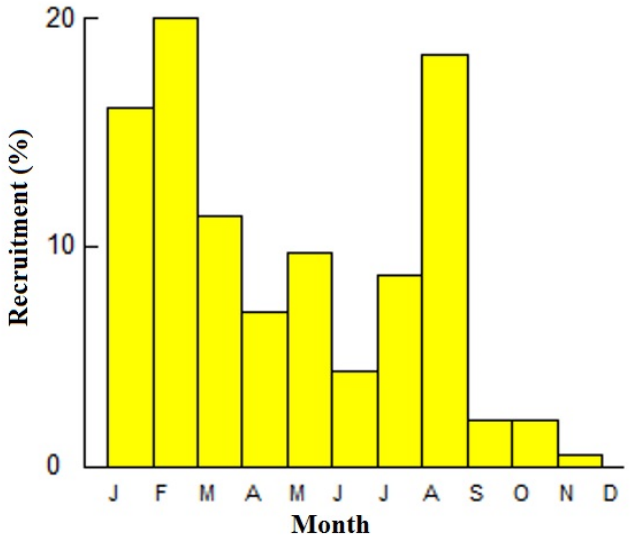

Fig. 7 — Recruitment pattern of *D. incarnatus*

period along the south west coast of India[3]. Such events affect population density of intertidal organisms in the world. In the present study, the maximum density (1885 ind. m^{-2}) of clams was recorded during December 2004. A large number of young ones were observed in this month. Nayar[16] observed that a maximum of 5113 ind.m^{-2} for *D. cuneatus* from Mandapam in south east of coast of India. In the current study, the lowest density (22 ind.m^{-2}) was recorded during monsoon season. Fluctuation of population density may be due to the severe wave action during monsoon season. Victor and Subramoniam[17] reported the population density of larger species of donacid, *i.e. D. cuneatus* from three beaches of Madras coast. Marina beach supported a population 16 times greater in size and 14 times denser compared to Mahabalipuram, and 2.5 times greater in size and 2.8 times as dense as that of Thiruvanmiyur. They suggested that beach slope seemed to play a significant role in availability of *D. cuneatus* among the various environmental parameters. The wedge clams like *D. incarnatus* and *D. denticulatus* must have the ability to re-burrow in order to maintain an optimal position or burrow deep enough to avoid the disturbance[18,19]. Thippeswamy[2] reported that the biomass (total weight) of small-sized wedge clam *D. incarnatus* varied from 124 g.m^{-2} (October 1984) to 1892 g.m^{-2} (January 1985) at Panambur. The biomass reported for *D. incarnatus* from Panambur was very higher than that of *D. incarnatus* reported from our study area.

The largest sized clams were recorded in the size group of 26-28 mm class interval and this size was reached when they were about 15 months old. Thus, the population comprises individuals of more than one-year age. Alagarswami[20] reported growth of 19.5 mm for *D. faba* by the end of the first year of life and 22.5 mm at the end of second year of life. In the case of *D. cuneatus,* Talikhedkar *et al.*[21] reported that the sizes of 13-14, 21-22 and 22-23 mm occurred in 1st, 2nd and 3rd years respectively. Thippeswamy and Joseph[1] recorded that the life span of *D. incarnatus* was little above one year (<15 months) in Panambur beach. From the sandy beach at Benaulim (Goa), Nair *et al.*[5] recorded that *D. incarnatus* attained an average monthly growth of 2.2 mm for one year. In the present study, the life span of *D. incarnatus* was around one year and a half year. Growth rate of juvenile clams was rather high during the first few months after settlement. Life span of *D. incarnatus* in the present study was more or less similar when compared to the life span of *D. incarnatus* elsewhere[1,5,6], *D. hanleyanus*[22,23] and *D. denticulatus*[24] respectively. The life span of *D. incarnatus* in the present study was more than *D. spiculum*[6] as well as different *D. tumida*[25], but short compared to *D. cuneatus*[16,21], *D. faba*[20,26], *D. variabilis*[25], *D. trunculus*[27,28] and *D. hanleyanus*[29].

The von Bertalanffy growth parameters of Donax spp. from different geographical regions are presented in Table 1. The L_∞ value (28.35 mm) in the present study is lower when compared to the value (30.94 mm) recorded by Thippeswamy and Joseph[1] for the *Donax incarnatus*, but higher than the value recorded by Singh *et al.*[25]. Present estimate value (K = 1.70) is almost similar to the growth rate (K= 1.79) of small wedge clam like *D. denticulatus*. The values of K determined by Nair *et al.*[5], Thippeswamy and Joseph[1], Singh *et al*.[25] and Ansell *et al*.[6] are lower than our present value, whereas the value of L_∞ reported by Thippeswamy and Joseph[1] is highest in *D. incarnatus* in India. Most species of *Donax* have a short life span of 1-2 years[30]. Along the French Atlantic coast, Ansell and Lagardère[31] observed longevities for *D. trunculus* and *D. vittatus* were 5 and 3.5 years respectively. Estimates of L_∞ and K of *D. incarnatus* in the present study are quite different when compared to the values of such large-sized wedge clam, *D. serra*[32,33]. Donn[34] reported the maximum size of wedge clam, *D. serra,* among *Donax* spp.

Table 1 — von Bertalanffy parameters L_∞ (mm), K (yr^{-1}) and ϕ' of donacids from several geographical regions for *Donax* species. Climate areas are: tropical/subtropical (X), temperate (Y) and upwelling (Z)

Species	L_∞	K	ϕ'	Climate area	Location	Sources
Donax incarnatus[a,d]	25.13	0.09	1.86	X	India	Ansell *et al*.[6]
D. incarnatus[a,d]	29.04	0.09	1.86	X	India	Ansell *et al*.[6]
D. incarnatus[a,d]	20.06	0.09	1.55	X	India	Nair *et al*.[5]
D. incarnatus[a]	30.94	0.16	2.19	X	India	Thippeswamy and Joseph[1]
D. incarnatus[a]	28.35	1.70	3.14	X	India	Present study
D. cuneatus[a]	22.87	0.06	1.48	X	India	Nayar[16]
D. cuneatus[a,d]	33.02	0.04	1.67	X	India	Talikhedkar *et al*.[21]
D. faba[a,d]	26.15	0.10	1.84	X	India	Alagarswami[20]
D. faba[a]	26.67	0.89	2.80	X	India	Singh *et al*.[26]
D. scortum[a]	70.88	0.64	3.51	X	India	Tenjing[7]
D. denticulatus[a]	18.50	0.43	2.17	X	Venezuela	Vélez *et al*.[41]
D. denticulatus[a]	31.47	1.48	3.17	X	Venezuela	García *et al*.[24]
D. denticulatus[a]	30.20	1.79	3.21	X	Venezuela	Marcano *et al*.[42]
D. dentifer[a]	29.30	0.62	2.73	X	Colombia	Riascos and Urban[35]
D. vittatus[a]	33.15	0.61	2.83	Y	France	Ansell and Lagardère[31]
D. vittatus[a]	29.76	1.32	3.07	Y	France	Ansell and Lagardère[31]
D. vittatus[a]	35.90	1.01	3.11	Y	France	Ansell and Lagardère[31]
D. vittatus[a]	31.28	1.06	3.02	Y	France	Ansell and Lagardère[31]
D. trunculus[a,c]	43.48	0.45	2.93	Y	France	Ansell and Lagardère[31]
D. trunculus[a,c]	36.33	0.70	2.97	Y	France	Ansell and Lagardère[31]
D. trunculus[a,c]	35.55	0.79	3.00	Y	France	Ansell and Lagardère[31]
D. trunculus[a,c]	32.25	0.68	2.85	Y	France	Ansell and Lagardère[31]
D. trunculus[a,c]	38.22	0.70	3.01	Y	France	Ansell and Lagardère[31]
D. trunculus[a,c]	38.41	0.72	3.02	Y	France	Ansell and Lagardère[31]
D. trunculus[a,c]	39.78	0.74	3.07	Y	France	Ansell and Lagardère[31]
D. trunculus[a,c]	39.70	0.77	3.09	Y	France	Ansell and Lagardère[31]
D. trunculus[a]	46.00	0.58	3.09	Y	Spain	Ramon *et al*.[27]
D. trunculus[b]	41.80	0.71	3.09	Y	Spain	Ramon *et al*.[27]
D. trunculus[a]	47.30	0.58	3.11	Y	Portugal	Gaspar *et al*.[44]
D. trunculus[a]	47.56	0.30	2.83	Y	Italy	Zeichen *et al*.[28]
D. hanleyanus[a]	33.00	0.80	2.94	Y	Uruguay	Defeo[45]
D. hanleyanus[a]	26.40	0.80	2.75	Y	Brazil	Cardoso and Veloso[35]
D. hanleyanus[a]	28.50	0.90	2.86	Y	Brazil	Cardoso and Veloso[35]
D. hanleyanus[a]	44.00	0.47	2.96	Y	Argentina	Herrmann *et al*.[29]
D. hanleyanus[a]	44.00	0.48	2.97	Y	Argentina	Herrmann *et al*.[29]
D. serra[a]	82.00	0.28	3.28	Z	South Africa	de Villiers[32]
D. serra[a]	75.00	0.43	3.39	Z	South Africa	de Villiers[32]
D. serra[a]	82.00	0.28	3.27	Z	South Africa	de Villiers[32]
D. serra[a]	78.00	0.32	3.29	Z	South Africa	de Villiers[32]
D. serra[a]	82.00	0.27	3.27	Z	Namibia	Laudien *et al*.[33]
D. marincovichi[a]	46.00	1.00	3.33	Z	Peru	Arntz *et al*.[43] - before El Niño
D. marincovichi[a]	35.00	1.17	3.16	Z	Peru	Arntz *et al*.[43] - during El Niño
D. marincovichi[a]	42.00	0.70	3.09	Z	Peru	Arntz *et al*.[43] - after El Niño

[a] *Age estimated from length-frequency distributions*

[b] *Age estimated from hyaline growth rings*

[c] *Age estimated from external growth rings*

[d] *Values calculated on monthly basis from raw data reported by the authors*

In our study, the natural (*M*) and fishing mortality (*F*) rates were 2.61 and 2.57 yr^{-1} respectively. Mortality of the adult clams, *Donax cuneatus* was highest during October-November and June-July due to changes in salinity and temperature of the inshore waters[16]. Thippeswamy and Joseph[1], and Riascos and Urban[35] also reported that total mortality occurred due to changes in salinity. Further, Thippeswamy and Joseph[1] suggested that grain size of sandy beach also involved in the mortality of donacid. Garcia *et al.*[24] reported the total mortality (*Z*) of *D. denticulatus* estimated for larger individuals (>22 mm) was high (2.93 yr^{-1}). In a case, parasitic interactions and interspecific interactions generally have been shown to play a role in mortality events[36]. In the present study, the total mortality (5.18 yr^{-1}) was higher when compared to the above values. McLachlan[37] and McLachlan and Van der Horst[38], working with *D. sordidus* on several beaches in South Africa, found similar values of total mortality (1.27 and 1.98 yr^{-1}). However, *D. incarnatus*[6] (Z = 6.24 and 8.72 yr^{-1}) and *D. spiculum*[39] (Z = 22.67 yr^{-1}) showed higher mortality values. These agree with high mortality reported from Karnataka coast (south west coast of India). Thus, as in marine species, the life span increases and mortality decreases for *Donax* species from tropical to temperate regions. The exploitation level (*E*) was 0.50 and seemed just to be the optimum level of exploitation (E = 0.50). The current value of *E* shows that the stock of *D. incarnatus* was found to be at the optimum level in the investigated area. Gulland[40]. This is based on the assumption that a stock is optimally exploited when the fishing mortality (*F*) equals natural mortality (*M*), or $E = (F/Z) = 0.50$.

Conclusions

The growth parameters and mortality rates described in the present study can provide important guidelines for fishery management of the wedge clam, *Donax incarnatus*. The result also indicates that the population studied was not overexploited. To maintain this valuable resource, the exploitation rate should therefore be monitored based on the optimum level.

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