Population dynamics of the edible rock oyster *Saccostrea cucullata* (Born, 1778) along the south-west coast of India

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**ABSTRACT**

For the management of molluscan stocks, knowledge of various population parameters and exploitation level of the population are needed. The present study assessed the population dynamics on the rock oyster *Saccostrea cucullata* (Born, 1778) in Karnataka State, south India. The specimens of *S. cucullata* were collected from Baindur rocky beach at monthly intervals from June 2010 to May 2011. Asymptotic length ($L_\infty$) estimated was 57.8 mm and growth coefficient ($K$) was estimated at 1.4 year$^{-1}$. The sizes attained were 45.30, 54.72 and 57.04 mm at the end of first, second and third years of age, respectively. Total mortality ($Z$) was 5.24 year$^{-1}$. Natural mortality ($M$) and fishing mortality ($F$) were 1.40 and 3.84 year$^{-1}$ respectively. The life span of *S. cucullata* was estimated as 2.5 years approximately. Exploitation level ($E$) was computed as 0.73, indicating that the fishery of *S. cucullata* in the coastal waters of Karnataka is overexploited.

Keywords: Age, Exploitation, Growth, Karnataka, Mortality, Recruitment, Rock oyster, *Saccostrea cucullata*

**Introduction**

The rock oyster *Saccostrea cucullata* (Born, 1778) is a tropical edible species widely distributed in the littoral zone of Indo-Pacific, Eastern Atlantic and the Mediterranean (Poutiers, 1998). In northern Australia, China, Thailand and India, this oyster is cultivated in backwaters and is quite popular in local markets (Jarayabhand and Thavornyutikar, 1995; Nell, 2001). *S. cucullata* is abundant on the south-west coast of India, where it often forms a distinct patch from mid to upper balanoid zone. Although not of commercial importance in India, *S. cucullata* is exploited by coastal fisherfolk who consume it and forms one of the major component in diets of these people when compared to other intertidal organisms.

Dye (1989) studied ecology of this species from the east coast of southern Africa and it is commercially exploited in Kenya. The east coast of southern Africa marks the southern limit of its distribution, but it is abundant around the Indian ocean (Kilburn and Rippey, 1982). Very little is known on the biology of *S. cucullata* in India. Recently, the ecology of *S. cucullata* was studied from the Sundarbans (Bhattacharyya et al., 2010). Growth was studied from Ashtamudi Lake, Kerala and Sundarbans, West Bengal (Kripa and Salih, 1999; Bhattacharyya et al., 2010). Seasonal variation in the biochemical composition and reproductive cycle were studied from the Indian Sundarbans and Mangalore respectively (Mitra et al., 2008; Sukumar and Joseph, 1988). Bivalve growth is mostly estimated by measuring the shell dimensions and rings or the volume of the animal (Deval, 2001). Allometry involves study of the change in proportion of various parts of an organism as a consequence of growth (Reiss, 1989).

Competitor, natural enemies including predators and environmental stresses are the major causes of mortality, other than natural senescence in oysters (Quayle, 1980). Much research has been undertaken to relate mortality of oyster with various physical and biological factors, namely temperature (Helen, 1997), salinity variations (Kripa and Salih, 1999), mud and silt accumulation (Awati and Rai, 1931), pollution (Wang et al., 2011), food deficiency (Bhattacharyya et al., 2010), competition for space and food (Lin and Tang, 1980), predation (Taylor, 1990; Helen, 1997), parasitic infections (Robert et al., 1991) and epibiont interference (Awati and Rai, 1931). Predation is an important factor causing oyster mortality (Helen, 1997). Although literature on rock oysters are available from all the Indian coastal regions, there seems to be very little attention paid towards the study on their population dynamics. The present paper gives data on growth, age, recruitment, mortality and exploitation rate of the edible rock oyster, *S. cucullata* from Karnataka.

**Materials and methods**

**Study area**

Karnataka State located in the southern part of India has three coastal districts viz., Dakshina Kannada, Udupi and Uttara Kannada. The study area in Baindur (Fig. 1)
is a rocky shore beach located near to the Someshwara Temple, in Udupi District (Fig. 1).

**Sample processing**

*S. cucullata* samples (Fig. 2) were collected from rocky intertidal zones of Baindur, (13°52’N; 74°36’E) from June 2010 to May 2011. Oysters were collected with the help of hammer and chisel, as the colonies of this oyster grow on hard rocks making them very difficult to remove. The oyster samples collected were cleaned with tap water and blotted using a blotting paper. A total of 2328 *S. cucullata* ranging in size from 4.7 to 55.2 mm were analysed. The length (the maximum distance along the long axis of the shells) was determined to the nearest of 0.1 mm (FAO, 1998).

**Data analysis**

For estimating von Bertalanffy growth parameters viz., asymptotic length (*L*∞) and growth constant (K), the length measurement data for one year were pooled month-wise and grouped into length classes of 4.2 mm intervals and analysed using ELEFAN (Electronic Length Frequency Analysis) from FiSAT software (Gayanilo et al., 2005). Estimates of *L*∞ and K were used to estimate the growth performance index (ϕ) (Pauly and Munro, 1984) of *S. cucullata* using the equation, ϕ = 2 log_{10} L∞ + log_{10} K. From the values of L∞ and K, the growth curve was fitted using the von Bertalanffy growth equation (von Bertalanffy, 1938). The von Bertalanffy growth function (VBGF) is defined by the equation, L_t = L∞ [1 - e^{-K(t-t_0)}], where L_t is the length at time t, e is the base of the natural logarithm, t the time of observation and t_0 is the hypothetical age when the length is zero (Newman, 2002). The parameter t_0 of the growth equation was estimated using the equation (Pauly 1983): log (- t_0) = - 0.3922 - 0.2752 log (L∞) - 1.038 log (K).

Taking into account that non-linear growth functions are difficult to compare, several authors demonstrated the suitability of composite indices for overall growth performance (OGP) for inter- and intra-specific comparisons (Pauly, 1979; Munro and Pauly, 1983). The OGP equation derived was OGP = log [K(L∞)^3]. The total mortality (Z) was estimated from length converted catch curve method following Pauly (1984). The natural mortality coefficient (M) was determined using M ≈ K approximation (Gayanilo and Pauly, 1997; Jayawickrema and Wijeyaratne, 2009). and fishing mortality coefficient (F) was estimated by subtracting M from Z. The exploitation rate (E) was calculated from the equation of Gulland (1965), i.e., E = F/Z = F/F + M. The recruitment pattern was obtained by projecting the length-frequency data backwards on the time axis using growth parameters (Moreau and Cuende, 1991).

**Results**

**Growth parameters**

Asymptotic length (*L*∞) estimated was 57.8 mm and the growth coefficient (K) was 1.4 years for *S. cucullata*. The growth curve using these two parameters is shown over the length frequency distribution in Fig. 3. The t_0 obtained was -0.094 and growth performance index (ϕ')
was found to be 3.67 (Fig. 4) in the present study. The 95% confidence interval for maximum length (56.16 mm) was between 53.06 and 59.25 mm. The calculated overall growth performance (OGP) of *S. cucullata* was 5.43.

**Age and growth**

Using the growth parameters, growth and age of *S. cucullata* were calculated. The growth rate and the absolute increase in age are presented in Fig. 5. The sizes attained by *S. cucullata* were 45.30, 54.72 and 57.04 mm at the end of first, second and third years of age, respectively. The average growth rates for *S. cucullata* from first to third years were 3.78, 0.78 and 0.19 mm respectively. The lifespan of this species reached up to approximately 2.5 years.

**Recruitment pattern**

The recruitment pattern of *S. cucullata* was continuous throughout the year with two major peaks in April and September (Fig. 6). The percent recruitment varied from 1.03 to 18.18 in the present study. The highest and lowest recruitment percentage were observed in April and January respectively.

**Mortality and exploitation**

The total mortality (*Z*) was estimated as 5.24 year⁻¹ using the length converted catch curve (Fig. 7). The natural
mortality (M) and fishing mortality (F) were 1.40 and 3.84 year\(^{-1}\) respectively. exploitation rate (E) obtained for \(S. \text{cucullata}\) in the present study was 0.73.

**Virtual population analysis (VPA)**

The length structured virtual population analysis (VPA) of \(S. \text{cucullata}\) is presented in Fig. 8 which indicated that the minimum and maximum fishing mortalities were 0.0856 and 4.4486 year\(^{-1}\) at the midlengths of 6.6 and 48.5 mm respectively. The fishing mortality (F) was high over the mid lengths from 35.9 to 52.7 mm.

![Graph showing mortality estimation of \(S. \text{cucullata}\) using Pauly's linearised length converted catch curve method](image1)

![Graph showing length-structured virtual population analysis of \(S. \text{cucullata}\)](image2)

**Discussion**

In the present study, the \(L_\infty\) was 57.8 mm and \(K\) was 1.4 year\(^{-1}\) when the \(t_0\) was -0.094 year. From these parameters, growth rate and age were calculated. Arkhipkin et al. (2017) reported the growth in terms of shell height of \(S. \text{cucullata}\) pooled from all sampling sites in Ascension Island which was described by the von Bertalanffy growth model. The population asymptotic average shell height \((L_\infty)\) reported by Arkhipkin et al. (2017) was 86.06 mm, the growth coefficient, \(K\) was 0.234 and the \(t_0\) was -0.69. Among these three parameters, the value of \(L_\infty\) is much higher than that of the \(L_\infty\) reported in the present study. As reported in mussels (\(Perna \text{viridis}, \text{Modiolus auriculatus}\)) and clams (\(Donax scortum, D. \text{faba}\)), the fastest growth in \(S. \text{cucullata}\) was observed during the first year of ontogeny (Singh et al., 2011; Tenjing et al., 2016, 2017a, b; Hemachandra et al., 2017).

Morton (1990) and Chiu (1997) found that \(S. \text{cucullata}\) has a short life span, especially in the peripheries of their ranges, with the majority of animals living just over two years. The longevity of this species estimated in the present study was 2.5 years. It has been suggested that such a shortlife cycle in this oyster is usually a result of harsh environmental conditions with exposure to pollution and high temperatures in nearshore areas (Krishnakumari et al., 1990; Davenport and Wong, 1992; Mtanga and Machiwa, 2007).

Recruitment of \(S. \text{cucullata}\) involves a sequence of steps viz., reproduction, larval dispersal, settlement and survival of spat. Recruitment failure may result from problems arising at any of these steps. It seems unlikely that lack of gonadal output is the primary cause of poor recruitment. The highest and lowest recruitment percentages were observed during summer and winter respectively in the present study. Lasiak (1986) studied reproduction of this species in Transkei coast of South Africa, which indicated a well defined spawning period from February to March during which over 40% of the animals examined were in spawning condition. The answer must therefore be sought in the vagaries of larval dispersal and/or post-settlement survival. Numerous factors affect post-settlement survival. Survival rate of other species like barnacle cyprids totally depends on temperature (Lewis, 1986). Lasiak (1986) reported that one of the most important physical factors affecting recruitment of bivalves, is high temperature on rock surface during hot days which leads to associated desiccation stress. Intertidal oysters often suffer from high temperature and face mortality when abnormally high temperatures coincide with unusually low mid-day tides (Dakin et al., 1952).

Rocky shores along with its ambient environment are conducive for oysters and their larval settlement. Limpets are important predators in the upper balanoid zone of rock (Dye, 1988). These gastropods constitute a source of indirect predation by bulldozing newly settled larvae (Denley and Underwood, 1979; Branch, 1981; Underwood et al., 1983). According to Quayle (1980), predators of oysters are fish, crab, snails, starfish and flatworms. Only young ones which settle in crevices or small depressions in the rock surface, or which grow rapidly to a size which exceeds the range over which bulldozing is effective, will
survive and get recruited to the adult population. This number appeared to be very small in the present study. Dye (1989) stated that Thais dubia and Morula granulata are the major molluscan predators of S. cucullata in east coast of southern Africa. The low natural mortality (M) found in nature reserves suggests that the effect is minimal. The M value of 1.4 estimated in the present study could be due to predation in the study area. S. cucullata is consumed by coastal fisherfolk in India (Maran and Ayyakkannu, 2002). According to Gulland (1965), the yield is optimised when F = M. On the other hand, when E is more than 0.5, the stock is overexploited. In the study area, S. cucullata is consumed by fisherfolk regularly and the oyster bed in the rocky habitat of Baindur was found to be subjected to overexploitation (E = 0.73).

Temperature might interact with other environmental attributes, such as salinity and food availability, as a main factor to define the growth and age. The present results give an overall idea about the relative growth and age of S. cucullata. However, for specific biological evaluation of the growth progression, long-term monitoring is required, which would help to understand the dynamics of this species.

Acknowledgements

The author is grateful to the authorities of Mangalore University, Karnataka, for the facilities provided and to the University Grants Commission, New Delhi for providing the financial assistance [BSR-UGC Meritorious Fellowship No. 4-1/2008(BSR)].

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Population dynamics of *Saccostrea cucullata*

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