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Growth and biometric relationship of the Indian pearl oyster *Pinctada fucata* (Gould) under long term onshore rearing system

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Abstract

Pinctada fucata, the Indian pearl oyster was cultured under land-based system for more than seven years. The maximum growth in length and weight was reached at about 3 years. The oysters were suitable for first seeding from about 9 months. The scope for producing larger pearls was more from about 2 years. They attained maturity from 6 months onwards and spawning was found to be continuous until the age of five years. After 3 years, they lost the power of attachment with byssal threads. After 5 years the gonads shrank in size with no development of gametes and pearls of 5-6 mm size could be produced from these oysters. However, the mantle ('Saibo') was active and capable of producing pearl sac and suitable for implantation. The length-weight, length-thickness and weight-thickness relationships were derived and presented. The weight was important, which is directly related to thickness and ultimately useful for planning the size of beads for seeding operations.

Keywords: *Pinctada fucata*, age and growth, length-weight relationship, *Saibo*

Introduction

The Indian pearl oyster *Pinctada fucata* (Gould) is distributed mostly along the Southeast and Northwest coasts of India (Algarswami, 1991). It is sparsely distributed along Visakhapatnam coast. It is the most convex of all species with an increase in ratio of thickness to dorso ventral measurement (DVM) with age (Hynd, 1955). The Japanese are able to produce pearls up to a maximum of 10 mm size from this species (Gervis and Sims, 1992). In India, the standard pearl produced under farm conditions is mostly 3-5 mm in the age group of 1-2 years (Dev, 1993). Growth studies are essential for planning farm operations and other phases like seeding, etc. Acceleration of growth by manipulating other biological parameters like feeding, density, etc will have considerable impact on the economic operation of pearl culture farms. Studies on growth of *P. fucata* have been made on sea based pearl culture technology, in Australia (Tranter, 1959); Korea (Yoo *et al.*,1986) and *P. fucata martensii* in Japan (Numaguchi and Tanaka, 1986 a, b). In India, age and growth studies mostly along southeast coast and recently in southwest coast have been conducted (Alagarswami and Chellam, 1977; Chellam, 1988). Mohammed *et al.* (2006) opined that faster growth is advantageous for reducing preliminary grow-out phase while low growth rates favour the final coats of nacre on a pearl before harvesting.

Very few protected areas along the Indian coast are suitable for pearl culture. No ideal sheltered bays or lagoons are available in the Indian mainland compared to other pearl producing countries. To overcome this problem attempts should be made to find out alternative methods suitable for Indian sea conditions to improve farming technology and production of high quality pearls (Dev, 1993). To solve this problem, the land based (onshore) technology of pearl culture has been developed (Syda Rao and Devaraj, 1996) and standardized (Syda Rao, 2004, 2005). The land based culture system is less risky compared to open sea pearl culture (Intes, 1995; Ito and Imai, 1955; Vacelet *et al*., 1996; Nagai *et al.*, 1996) and provides an opportunity to combine all key environmental factors together at optimum level through good planning and management. The problem of borers, foulers and predators is almost eliminated in the land-based system resulting in better growth and high survival rate (Syda Rao and Devaraj, 1996). The present study pertains to the age and growth studies of the Indian pearl oyster, *P. fucata* on land based (onshore) technology for production of larger pearls.

Materials and methods

The land based pearl culture technology is used in the study as per the procedures described by Syda Rao and Devaraj (1996) and Syda Rao (2001, 2004). This technology has been patented (No.DEL/138/2001). In view of this fact some critical information of commercial values are not presented here. The age and growth were recorded from 1998 to 2005 spreading for a period of above 7 years.

The pearl oysters were brought from Tuticorin, India and were reared to adult size under onshore conditions. Under this system the pearl oysters were grown in cement concrete tanks at a density of 45 nos./ m^2 with seawater drawn from sea through a pipeline and fed with cultured species of micro algae *i.e. Chaetoceros calcitrans* and *Isochrysis galbana*. The oysters attained maturity under captive conditions. The spawning was induced by standard thermal stimulation and the larvae were reared following the techniques of Alagarswami *et al.* (1983). The spat were reared up to 5 mm (3 - 10 mm) in the hatchery and later transferred to the outdoor nursery tanks. During nursery rearing the spat density was 5000nos./m^2. The seawater was exchanged at a minimum rate of 10% every day and the oysters were fed with a mixed diet of *C. calcitrans, I. galbana* and *Nannochloropsis salina* at an appropriate ratio. The concentration of algal cells was maintained continuously at 10000 cells/ml to 75,000 cells/ml till the oysters reached adulthood (> 45 mm). An enhanced rate of feeding was done continuously in the same range for the later period of rearing. The stocking rate was maintained at 50-60 oysters /m^2. They were fed through specially designed gravity oriented drip system to maintain the cell concentration to the desired level and to minimize the cost (Syda Rao, 2003). The salinity ranged from 18 ppt to 35 ppt. The ambient temperature ranged between 16 ^{0}C to 35 ^{0}C. There were no foulers or borers in the land based system. Occasionally external algal settlement noticed was gently scrubbed of as and when required. The growth was monitored and estimated as regards to length (DVM), weight (TWT) and thickness (T) for a period over 7 years. Shell dimensions of the oysters, excluding the growth processes were measured using Vernier calipers and the total weight by electronic balance (Sartorius, d=0.1 mg) as per Hynd (1955). He described the dorso ventral measurement (DVM) as the greatest dimension of the oyster measured at right angles to the hinge line and the thickness (cup width) as the maximum distance between the external surfaces of the two valves when both are closed. The hydrological (temperature, salinity and total suspended solids) were monitored during the period. The relationship between the above parameters were calculated by least square methods by the equation, $y = a + bx$, where a is the intercept and b the slope. The hydrological parameters were monitored and documented in weekly intervals.

Results

The oysters attained a length of 40.65 ± 5.52 mm (± standard deviation), (29-48 mm) and weight of 10.69 ± 2.18 g (8-10 g) after six months. They reached a DVM of 56.17 ± 6.93 mm with a range of 45-65 mm and weight of 20.37 ± 4.88 g (10-29 g) after one year. At the end of second year they attained a length of 72.11 ± 7.99 mm (55-85 mm) with a corresponding weight of 46.42 ± 13.55 g (26-76 g). They reached a DVM range of 81.58 ± 10.08 mm (65-105 mm) and corresponding weight range was 64.97 ± 20.2 g (50-110 g) after three years.

After a period of 6 months the increase in DVM was 0.2 mm /day (mean value) while after 1 year 0.15 mm / day. They showed a maximum growth rate in the first 6 months as observed under onshore conditions. The increment was 0.04 mm /day after two years and 0.02 mm / day after 3 years. In the fourth year, it was 0.01 mm/ day and the increase in DVM was almost arrested afterwards with an average of 0.004 mm/day. In the case of total weight at the end of 6 months the increase was 0.06 g/day while after 1 year it was 0.05 g/day (Fig. 1). There was maximum increase in TWT during 1-2 year period at a rate of 0.07 g/day. During third year the growth in TWT was 0.05 g/day. In the fourth year it was minimum for DVM, weight and thickness. From five to seven years the growth was negligible in DVM and weight. The oysters have almost reached the senility stage. However, they were very active in feed consumption, adaptability to the changing water environment and the survivability was high. They reacted considerably to the external stimuli. However, the opening of valve was 2 to 3 times higher than that of 1-2 year old oysters. The gonadal sac was prominent and empty. It was possible at this stage to utilize these old oysters for implantation of 5-6 mm nucleus beads.

The thickness ranged from 5-16 mm with a mean of 11.95 ± 2.48 mm after 6 months and it was 18.02 ± 2.52 mm with a range was 13-23 mm after one year. However, the thickness was 27.4 ± 5.14 after the second year. In the third year, the thickness was 28.36 ± 3.59.

The Length (DVM)-weight relationship may be expressed as

Y (Weight) =1.6174 X (DVM) -70.126

It is clear that the weight increment is higher after 60 mm DVM (Fig. 2).

The relationship between length (DVM) and thickness (T) may be expressed as

Y (DVM) =0.2826 X (Thickness) + 3.94

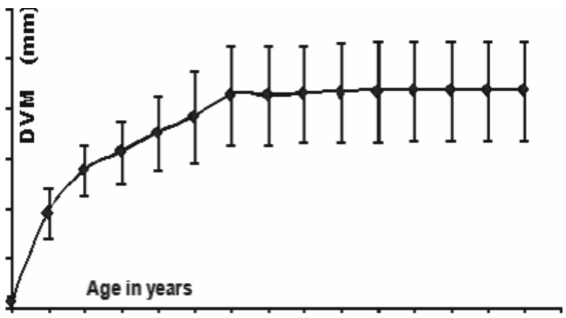

Fig.1. Growth of Indian pearl oyster *Pinctada fucata* over a period of culture with the changes in dorso ventral measurement (DVM). (Vertical lines indicate the range)

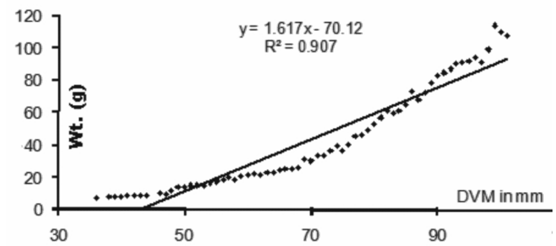

Fig. 2. DVM- weight relationship over a period of growth. Regression lines fitted for showing the relationships with the R^2 value.

The thickness (T) was observed to increase gradually with increase in DVM (Fig. 3).

The relationship between weight and thickness which is very useful for seeding operations (Fig. 4) may be expressed as

Y (Thickness) =0.1389X (Weight) + 18.225

The oysters attained first maturity at about 45 mm and spawned at frequent intervals. After three years most of

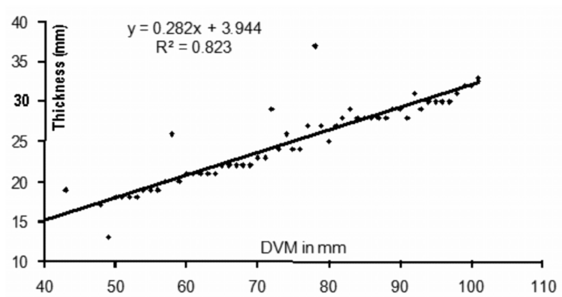

Fig. 3. DVM-thickness relationship of *P. fucata* grown under onshore culture system with the regression line fitted with R^2 value.

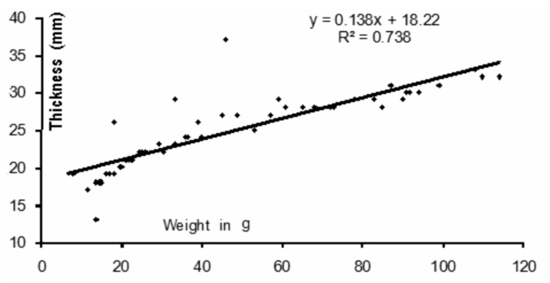

Fig. 4. Weight- thickness relationship of *P. fucata* with R^2 value and the regression line fitted to show the relationship over culture period.

them lost the power of attachment through byssal threads. However, they were actively feeding, maturing and regularly spawning. After five years, shrinking and almost empty gonads were observed. The size of the gonad was very much reduced comparable to the size of one year old and empty.

Discussion

In onshore culture system, under the controlled environmental conditions and continuous availability of feed, the growth was faster and mortalities were low (Syda Rao, 2005). Leighton (1979) identified food availability as the one of the major factors responsible for bivalve growth in suspended grow-out systems. Devanesan and Chidambaram (1956) reported that growth in DVM was 45 mm in first year in *P. fucata* in southeast coast of India. Mohamed *et al.* (2006) reported a growth of 69.8 mm in the first year of transplanted stock of this species in Kollam Bay of Arabian Sea while in the native stock it was 62.5 mm. According to them a sudden change to a favourable growing environment acts to spur growth performance indicating an immediate transplant effect. Further, due to increased availability of food in a very high primary productive tropical upwelling ecosystem of Arabian Sea (Nair and Gopinathan, 1981; Rajagopalan and Krishna Kumar, 2003) might have triggered the growth. Yukihara (1998) reported that *P. margaritifera* and *P. maxima* maintain high feeding rates over a wide range of environmental conditions. Numaguchi (1994) reported that the slow growth in *P. fucata martensii* was due to low food concentrations in Ohmura Bay. In the present study, growth of oysters attained a mean DVM of 56.17mm and 72.11mm in 1st and 2nd year with a maximum growth of 65 mm and 85 mm respectively. Continuous food availability may be one of the major factors that enhanced growth. The growth was continuous and uniform. In bivalves, it is fast initially and such higher rates in DVM in the juvenile phase were observed in the present study. According to Chellam (1988), the estimated L_{α} of *P. fucata* from Tuticorin farm was 79 mm with a K value of 0.075, which is close to the maximum observed size (80 mm) of mother oyster culture with r^2 value of 0.999. In the present study the maximum observed DVM was 105 mm at the end of three years. Literature on the long-term growth studies over a period of seven years is scanty

Devanesan and Chidambaram (1956) reported that growth in DVM was 45, 50 and 60 mm in first, second and third year and 72 mm in 6 years. The growth rates observed in the present land based system were comparatively better and the fast growing group of oysters attained a mean DVM of 81.58 mm with the maximum of 105 mm in three years (Fig. 1). The largest of this species recorded in India from the natural beds of Gulf of Mannar was 75 mm (wt.80g) in about 72 months, whereas those recorded from Gulf of Kutch was 86 mm with an estimated age of about 84 months (Rao and Rao, 1975). A record growth of about 105 mm and 110 g was achieved under onshore system in 3 years. The species inhabits preferentially in clearer waters as evidenced by the discontinuous distribution along the southeast and northwest waters of Indian sub continent. Mohamed *et al.* (2006) in their study in Kollam Bay suggested that the presence of abundant particulate matter and increase in productivity due to fluctuations in the physico-chemical parameters could have influenced the growth whereas in Tuticorin the hydrological parameters were relatively stable. The abundance of particulate matter and productivity resulted in decreased pumping activity for feeding by the oysters thereby conserving and utilizing this energy for somatic and shell growth. Urban (2000) concluded that no environmental factor is significantly correlated with growth but it tended to increase with increase in chlorophyll *a* indicating that phytoplankton abundance enhanced growth in *P. imbricata.*

Several studies have identified temperature as one of the main factors affecting the growth of pearl oysters (Gervis and Sims, 1992). Under onshore conditions the temperature could be manipulated suitably to the culture conditions and was maintained within a range of 24-28 ^{0}C though its range in the seawater drawn was 16 ^{0}C to 35^{0}C. Gokhale *et al.* (1954) indicated that a low temperature ranging between 23 and 27 ^{0}C was favourable for growth, and its cessation during summer months when temperature was high. O'connor (2002) found that the warmer Queensland waters promoted growth in *P. fucata* during the nursery and grow-out phases. The present study indicated that grow-out environmental conditions influenced the growth and the biometric relationship and the prevailing onshore culture system appeared to be congenial for the growth.

Growth and mortality are two of the most important parameters of the population dynamics. Culture in natural open sea conditions is subjected to many environmental as well as natural calamities (Intes, 1995). Further, growth and survival of pearl oysters are influenced by several environmental factors and the response to these variations during different life stages like spat and adult differ (Gervis and Sims, 1992). Boring and fouling organisms always pose problems in the pearl culture (Algarswami and Chellam, 1977; Mizumoto, 1964; Velayudhan, 1983). Our study for the last seven years revealed that the rate of mortality from a spat to implantation size (45 mm) was less than 10% due to controlled environmental management as well as the continuous feed availability. The mortality of the implanted oysters has been found to vary depending on the location of the farm site (Victor *et al*., 2003) and with the depth at which the farms are located (Jagadis *et al*., 2003). In the present study the rate of mortality in the post implantation period was 10%. Norton *et al.* (1996) stated that, in general, as it has been observed that for every 100 oysters operated on, approximately one third will die, one third will reject the shell bead and the remaining will produce mostly poor quality pearls. In our studies a survival of 80% from spat to production of pearls were experienced, mostly due to the needed intervention at each stage of rearing

The growth in *P. fucata* was not uniform in the cohort. There was always one fast growing group, a major group of medium growth and slow growing group of 'runts' in the same cohort. Present study revealed that the growth rate was not uniform and about 60-75% of the stock at the end of grow-out period of one year attained a suitable size for implantation. The rest were stunted in growth, due to inherent reasons. Heterogeneity has been reported in natural populations of in the same geographical locations (Algarswami and Chellam, 1977; Velayudhan *et al*., 1996). Mohamed *et al.* (2006) observed that when genetically similar stock was grown in two different locations, those in a more nutritionally rich environment outgrew the parent stock. However, Seed (1976) concluded that changes in shell morphology in the same population are essentially due to environmental factors while it is reported that both environment and genetic factors influence shell characteristics (Wada, 1984). According to Pit and Southgate (2002) small spat do not catch up larger individuals within a cohort. However, these runts are capable of similar growth rates to large pearl 'oysters' when provided with appropriate conditions. The present study clearly suggested that oysters grown up to four years, the fast growing group could be seeded from around 9 months onwards and majority reached operative size by about 12-18 months. Possession of large proportion of 2-3 years aged population was very advantageous for producing larger pearls up to 9 mm on a continuous basis. Under the present culture system as the production of spat was not a limiting factor, culling would not affect economics of pearl culture.

The external growth parameters like DVM, weight and thickness are all interrelated and have bearings on the size of nucleus, which can only be known at the time of operation when technicians get a measure of the available space within the pearl oyster gonad. According to Kanauer and Taylor (2002a), pearl nuclei size required for implantation can be correctly predicted based on wet weight measurements of *Pinctada maxima*. Our experience suggests that monitoring weight frequency within 18-24 months was more appropriate for prediction of nuclei size.

Galtsoff (1931) found an allometric relationship for length-weight relation for the Hawaiian pearl oyster and the equation holds true for all sizes of shells, in spite of their change in shape from immature to adult stage. Alagaraja (1962) found that the straight-line equation described the relationship. A similar result has been obtained in the present study.

Hynd (1955) reported that *P. fucata* is the most convex of all species of pearl oysters with an increase in the ratio of thickness: DVM with age. Chellam (1988) observed a thickness of 19 mm, 27.1 mm, 31.8 mm in first, second and third year respectively in Gulf of Mannar. Gokhale *et al.* (1954) observed in the Gulf of Kutch that they attained 21.8 mm thickness at the end of second year and 25 mm in the third year. Under on shore culture condition, similar growth in thickness was obtained as observed by Chellam (1988). Mohamed *et al.* (2006) reported that at Kollam Bay in the southwest coast of India, growth attained at the end of first year was similar to that obtained at the end of second year in the Gulf of Mannar and Gulf of Kutch. The natural and hatchery bred *P. fucata* stocks in the Gulf of Mannar along the southeast coast and in the Gulf of Kutch (in the Arabian Sea) along the northwest coast attained a low shell thickness that restricted the size of the nuclei. In the present study, a stock with 65-70% of oysters with thickness above 21 mm could be obtained in a period of 18 months, or 27.4 mm at the end of second year for seeding of nuclei of size more than 5 mm. Kripa *et al*. (2007) used *P. fucata* of mean thickness 25.1 mm for implanting nuclei above 5 mm and got pearl production rate at an average of 21 and 24% for the 5 mm and 6 mm nuclei respectively.

The DVM–weight and the DVM-thickness relationships has more commercial applications (Figs. 2&3). Mohamed *et al.* (2006) opined that in *P. fucata*, thickness is also as important as weight. In the present investigation it was observed that majority of pearl oysters have attained thickness of above 25 mm and a weight of 50 g, in about 2-3 years. Although the size of bead insertion is finally decided after opening the oyster at the time of implantation, it may possibly be related to the thickness (Fig. 4). At this stage they are suitable for implantation with beads above 8 mm. As the extraction of pearls of all sizes without sacrificing the pearl oysters was successfully implemented under land based system (Syda Rao, 2005) it was very easy to re-use the animal, which have rejected the beads as well as those from which pearls were extracted, after allowing suitable convalescence period. Under land based culture system, with the availability of good proportion of aged population, it is possible to maintain a pool of pearl oysters as well as for larger size pearl production. Further, a good stock of oysters with desired characters can be used for brood stock, spat production and selective breeding.

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