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Growth and biometric relationships of the silver or gold-lip pearl oyster, *Pinctada maxima* (Jameson, 1901) under land-based culture system

G. SYDA RAO, PHALGUNI PATTNAIK* AND BISWAJIT DASH*

Central Marine Fisheries Research Institute, Post Box No. 1603, Ernakulam North P. O., Kochi-682 018, India

**Vishakapatnam Regional Centre of Central Marine Fisheries Research Institute, Vishakapatnam- 530 003, Andhra Pradesh, India*

e-mail: gsydarao@gmail.com

ABSTRACT

The spat of silver or gold-lip pearl oyster, *Pinctada maxima* (Jameson, 1901), collected from the hulls of mechanized fishing trawlers operating from Visakhapatnam were grown under land-based culture system. The pearl oysters were continuously fed with a mixed diet of micro-algae through a specially designed drip system. The growth in terms of dorso-ventral measurement (DVM), weight and thickness as well as the biometric relationships are presented. A maximum DVM of 141 mm and a maximum weight of 292 g were obtained in two years. The land-based culture technology originally developed and patented in India for *Pinctada fucata*, is also discussed with respect to suitability for culture of *P. maxima*.

Keywords: Biometric relationship, Growth, Land-based culture system, *Pinctada maxima,* Silver or gold-lip pearl oyster

Introduction

The silver or gold-lip pearl oyster, *Pinctada maxima* (Jameson, 1901) is recognized as the largest of all the species of pearl oysters in the world (Shirai, 1994). This is one of the fast growing (*K* value 0.2 to 0.5), commercially important pearl oyster species which can grow up to a dorso-vental measurement (DVM) of 300 mm and attain a weight of about 6 kg (Gervis and Sims, 1992). It is a protandrous hermaphrodite, maturing as male after first year and as female after two years (Rose *et al*., 1990). This species is distributed in the central Indo-Pacific from Myanmar to Solomon Islands. Australia and Indonesia are the leading countries in the culture of *P. maxima*. It is also cultured in Myanmar, Thailand, Philippines and Japan. This species produce the most lustrous and rare "golden or silver" south sea pearls of 12 to 18 mm size, starting from the age of 2 years at a size of about 120 mm (Rose *et al*., 1990). Published reports are available on research works carried out on various aspects like elucidation of reproductive cycle of the species (Rose *et al*., 1990), techniques for larval as well as spat culture (Rose and Baker, 1994), growth and mortality in hatchery as well as nursery culture (Taylor *et al*., 1997; Yukihara *et al*., 1998; Mills, 2000). However, Taylor *et al*. (1997) stated that there is a paucity of information on the optimal rearing conditions during nursery culture of *P. maxima*. This species has not been recorded along the Indian coast in spite of several surveys (Algarswami, 1983).

Very few regions along the Indian coast are identified as suitable for pearl culture. Further, availability of sheltered bays or lagoons are limited along the Indian coast unlike other pearl producing countries. To overcome these problems, attempts have been made to find out alternative methods, suitable for Indian conditions to improve pearl farming technology as well as quality of pearl production (Dev and Durairaj, 1993). The land-based technology of pearl culture was developed (Syda Rao and Devaraj, 1996) and standardized (Syda Rao, 2001; 2003; 2005) for the Indian pearl oyster, *Pinctada fucata*. The land-based culture system is less risky compared to pearl culture in the open sea as it provides an opportunity to maintain key environmental factors at optimum levels through proper planning and management. The problem of borers, foulers and predators is minimized in this system resulting in better growth and high survival rate (Syda Rao and Devaraj, 1996).

The objective of the present study was to assess the performance of *P. maxima* under land-based culture system.

Materials and methods

The study was conducted during 2003 - 2005 at the land-based pearl culture facility of the Regional Centre of the Central Marine Fisheries Research Institute, Visakhapatnam, India. The land-based pearl culture technology has been patented in India and is being practised for the species *P. fucata* (Syda Rao, 2001). In the present study, growth and survival of *P. maxima* was evaluated under land-based culture as per the procedures described by Syda Rao and Devaraj (1996) and Syda Rao (2001).

During March 2003, spat of *P. maxima* (113 nos. having DVM 11.64±2.64 mm) were collected from the hull of two mechanized trawlers fishing in Myanmar and

Indonesian waters, operating from Visakhapatnam Harbor. The spat collected were transferred to 1000 l capacity FRP tanks. The seawater for rearing was drawn from a filter installed in the sea bed to a slow sand filter in the rearing facility. The water quality parameters in the rearing tanks were kept close to natural coastal conditions to ascertain the suitability of the geographical location for culture of *P. maxima* and also to evaluate its adaptability pertaining to the environmental conditions.

Three species of micro-algae (*Chaetoceros calcitrans*, *Isochrysis galbana* and *Nanochloropsis salina*) were mono-cultured in batches for feeding the pearl oysters. Slow-sand filtered seawater was used for the production of micro-algae. For the maintenance of stock culture of algae, autoclaved filtered seawater was used. The indoor culture of algae was carried out using Guillards f/2 medium and Conway medium. Two hundred and fifty millilitre of the starter culture was used to inoculate 2 l/15 l plastic jars and subsequently, outdoor culture was done in 100 l capacity FRP tanks. This was used as inoculum for outdoor mass culture of micro-algae in round transparent 1000 l capacity FRP tanks, filled with slow-sand filtered seawater without any supplementary chemical nutrient source. Cell density of 1-1.5 million cells ml^{-1} was achieved within a period of 24 h for feeding directly to the oysters in the rearing tanks. For indoor culture in the temperature controlled facility (20-25 ^{0}C), 24 L photoperiod was maintained using fluorescent lighting. Out door mass culture was done in natural day light, with temperature ranging from 24 to 28 ^{0}C.

The spat (107 nos.) having DVM range of 5-15 mm (11.64±2.64 mm) were reared initially for a period of 3 months in 1000 l FRP rectangular tanks holding filtered seawater of salinity ranging from 18 to 35 ‰ (depending on the season), with gentle aeration. They were fed on a mixture of *C. calcitrans*, *I. galabana* and *N. salina* in the ratio 6:3:1 until they reached a mean DVM of 32.5 mm. They were fed continuously through a specially designed gravity oriented drip system through plastic tubes from an overhead feeding trough in order to maintain the algal concentration in the rearing system at 10,000-75,000 cells ml^{-1} (Syda Rao, 2003). Water quality parameters such as salinity, dissolved oxygen and pH were measured everyday and any deviation from the normal ranges were corrected through water exchange.

The pearl oysters were then distributed at a density of 50 nos. m^{-2} in 1000 l capacity FRP tanks and subsequently transferred to outdoor concrete tanks (10 m^3). With the advancement of growth, in every three months, they were graded by size and restocked at densities ranging from 50 to 10 nos. m^{-2} upto two years. Ten percentage of seawater in the tank was renewed daily after siphoning out fecal matter, and 100% water exchange was done at an interval of 10 days. External algal settlements were gently scrubbed off, as and when observed.

The growth was monitored at monthly intervals and morphometric measurements were estimated as regards to DVM, thickness (THK) in millimeters and weight (TWT) in grams. Shell dimensions of the oysters, excluding the growth processes were measured using Vernier calipers and the total weight were taken using an electronic balance (Hynd, 1955). The biometric relationships (DVM-TWT, DVM-THK and THK-TWT) were analyzed by fitting the equation, $y = a + bx$, using least-square method, where a is the intercept and b the slope. Logarithmic *vs* exponential regression was estimated for DVM-TWT and TWT- THK as their relationships were non-linear.

Results

The mean DVM (± SD) at the beginning of rearing was 11.64±2.64 mm. The growth was rapid in the initial months. The oysters attained a mean DVM of 55.51±7.12 mm after a period of six months. They reached 77±11.4 mm and 115.08±14.99 mm (mean DVM ± SD) at the end of one year and two years respectively (Fig. 1). During the initial 6 months, the average increment in DVM recorded was 7.31 mm $month^{-1}$, which was the maximum growth rate observed under land-based conditions while from 6 months to one year it was only 3.58 mm $month^{-1}$. The increase in DVM for the first year of rearing was 5.45 mm $month^{-1}$, while the increment was 3.17 mm $month^{-1}$ during the 2nd year. About 20% of the pearl oysters were found fast growing and another 20% were observed as very slow growing 'runts'. The rest of the individuals exhibited normal growth rate with intermittent short slow periods.

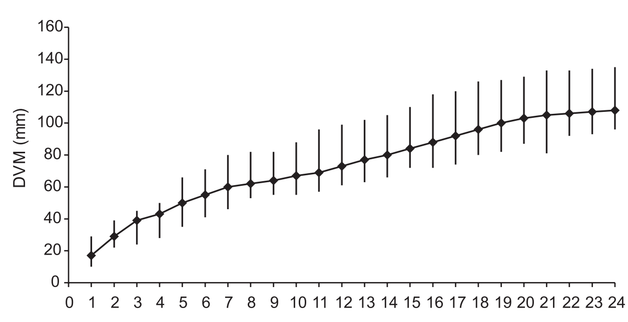

Fig. 1. Growth in terms of dorso-ventral measurement (DVM) of *P. maxima* grown under land-based culture system. Vertical lines indicate standard deviation (SD).

The weights of the oysters were recorded from 20 mm DVM onwards. During the initial period of growth (20-40 mm DVM), the weight increment was very slow (0.8-2.9g). From 50 mm (DVM) onwards, the weight increment took a lead over the length (Fig. 2). The mean weight after a period of six months was 19.18±7.19 g. They attained a mean weight of 47.76±19.2 g and 155.17±56.92 g

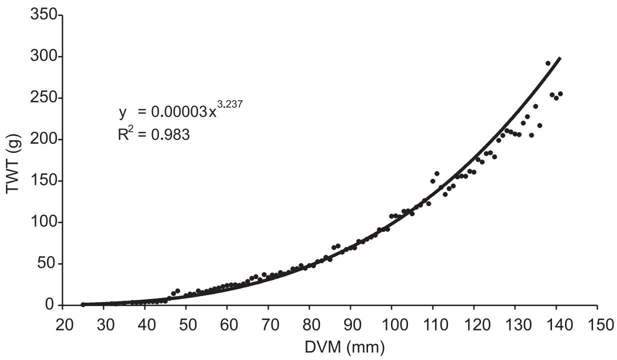

Fig. 2. Dorso-ventral measurement (DVM)-weight (TWT) relationship of *P. maxima* grown under land-based culture system showing the regression line fitted with R^2 value.

at the end of 1 and 2 years respectively. During the initial 6 months of rearing, the average increase in weight was 3.2 g month^{-1}, while from 6 months to 1 year, it was 4.76 g month^{-1}. The weight gain showed an increasing trend up to 18 months of growth (11.49 g month^{-1}), which was the maximum rate observed under land-based condition. From 18 months onwards the weight increment was only 6.41 g month^{-1} up to 2 years. The weight increment during the first year of rearing was 3.87 g month^{-1}, while the increment was 8.95 g month^{-1} during the second year. A maximum weight of 292 g was achieved at a DVM of 138 mm. The DVM-TWT relationship was calculated as:

$$TWT = 0.00003\ (DVM)^{3.237}$$

The TWT were more scattered after a mean DVM of 118 mm.

The increase in THK of oyster is an important parameter for pearl production. The relationship between DVM and THK of oysters was calculated as:

$$THK = 0.2258\ (DVM)^{0.166}$$

The THK was observed to increase relatively proportional to the increase in DVM upto 130 mm. After 130 mm, the growth in THK progressed more rapidly as indicated by the scattered points against straight line (Fig. 3). The mean THK at 60 mm DVM, was 14 mm and

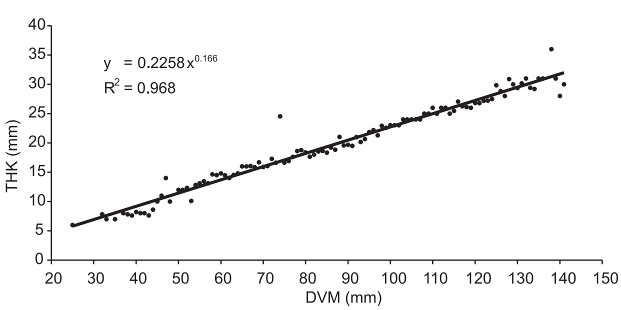

Fig. 3. Dorso-ventral measurement (DVM) - thickness (THK) relationship of *P. maxima* grown under land-based culture system. Regression line fitted for showing the relationships with the R^2 value.

at 80 mm DVM, it was 18 mm. However at 100 mm, the mean THK increased to 23 mm. At mean DVM of 112 mm (103 - 40 mm), the mean THK was 26 mm (23 - 33 mm). The THK in relation to TWT, which is useful for seeding operations was calculated as:

$$THK = 5.3999\ (TWT)^{0.3135}$$

The THK increased at a faster rate in relation to TWT up to 50 g. Later the increase in TWT was perceivable only with higher increments in TWT. It was observed that at a mean TWT of 50 g, mean THK was about 18 mm. At a mean TWT of 100 g, it was 23 mm and at 200 g, the THK was about 29 mm (Fig. 4).

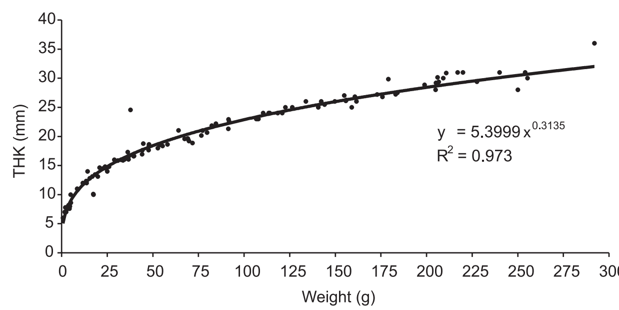

Fig. 4. Weight (TWT) - thickness (THK) relationship of *P. maxima* grown under land-based culture system with R^2 value and the regression line.

The survival obtained during the two year period was 91%. Six mortalities were recorded within the first month of rearing. Apart from this, four oysters died within two years. Photographs of juveniles and adults of *P. maxima* grown under land-based system are presented in Fig. 5 and 6 respectively. Gonad development was not observed in the oysters during the first year (max. DVM - 96 mm). During the second year (after 18 months), gonad development was noticed and they matured as males at a DVM range of 104-115 mm. The fully grown gonad

Fig. 5. Juveniles of *P. maxima* grown under land-based culture system.

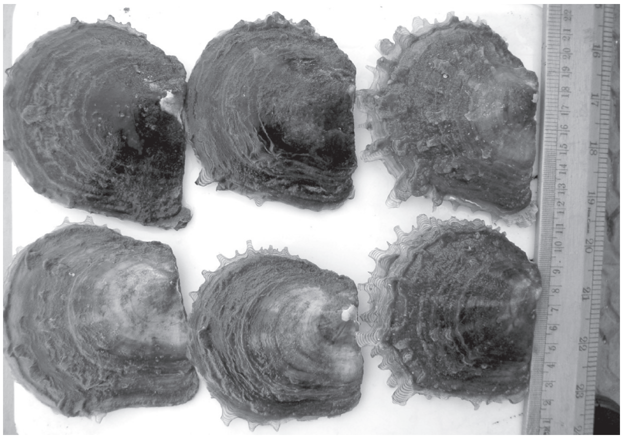

Fig. 6. Adults of *P. maxima* grown under land-based culture system

appeared light pink in colour. Under controlled environment, natural spawning yielded only sperm and inducement of spawning was not attempted. The secretion of byssal thread and attachment was observed during the first year of rearing. The byssal re-attachment to the substratum occurred almost the next day. During the latter part of second year, they lost the power of byssal secretion and hence failed to re-attach after removal. No disease was encountered in this system during the culture period. The occurrence of foulers and borers in the land-based system was also negligible.

The salinity of water in the rearing tanks ranged from 35 ‰ during March-June to 18 ‰ during November. The lowest salinity approached gradually during north-east monsoon and remained for a short period, a normal feature in this part of Bay of Bengal. The pH values ranged from 6.4 in May to 8.5 in November. The pH ranged from 7.8-8.4 during the rest of the months. The temperature of the seawater reached a peak at 32 ^{o}C in May and gradually declined to 24 ^{o}C during December-January. However, the water temperature in the rearing tanks were maintained within a range of 24-28 ^{0}C by storing the incoming water in separate holding tanks for a definite period, whenever required. The dissolved oxygen (DO) values in the rearing tanks ranged from 4.1 mg l^{-1} in May to 6.2 mg l^{-1} in November. The ambient atmospheric temperature ranged between 18 to 38 ^{0}C.

Discussion

The distribution of *Pinctada maxima* is limited as compared to other species of pearl oysters. Due to high commercial importance, propagation of this species in newer areas has been attempted. The present study made a maiden attempt for experimental culture of this species under land-based system and evaluated the growth, survival and maturity. In this system, under controlled environmental conditions with continuous availability of algal feed, growth was fast and mortalities were low (Syda Rao, 2004). Occurrence of foulers or borers was also negligible. Six mortalities recorded within the first month of rearing, could be attributed to the disproportionate feeding ratio and feeding rate or transplant related stress. In addition to this, four oysters died during the subsequent culture period. The mortality may be due to either high feeding intensity leading to pseudofaecus production (Syda Rao, 2007) or individual non-response to the culture environment at the particular stage of growth. Leighton (1979) identified food availability as one of the major factor responsible for bivalve growth in suspended grow-out systems. Mohamed *et al.* (2006) suggested that sudden change to a favourable environment with increased availability of feed triggers growth in *P. fucata*. In the present study, oysters attained a mean DVM of 77 mm and 115.08 mm in first and second year with maximum DVM of 96 mm and 141 mm respectively. The un-interrupted food availability under the land-based system may be one of the major factors that favoured good growth. Yukihara *et al.* (1998) reported that *P. margaritifera* and *P. maxima* maintain high feeding rates over a wide range of environmental conditions. They further revealed that at relatively higher food concentration, *P. maxima* was efficient at gaining energy that influenced higher growth rate (Yukihara *et al*., 1999). It has also been reported that *P. maxima* cannot live in tanks due to its huge feed requirement and other needs (Anon., 2003). However, our studies revealed that by feeding a mixture of individually cultured algae (*C. calcitrans*, *I. galbana* and *N. salina*) at a ratio of 6:3:1 and feed concentration of 10000-75000 cells ml^{-1}, good growth rate can be achieved.

Several studies have identified temperature as one of the main factors affecting the growth of pearl oysters (Numaguchi and Tanaka, 1986; Pass *et al*., 1987; Gervis and Sims, 1992; Yukihara *et al*., 2002). Under land-based conditions, the temperature can be manipulated to suit the requirement which was maintained within a range of 24-28 ^{0}C during the present study, though the temperature of the seawater drawn ranged from 24 ^{0}C to 32 ^{0}C. Yukihara *et al.* (2006) found significantly lower growth rates and lower survival of small oysters during winter compared to summer. O'Connor (2002) found that the warmer Queensland waters promoted growth during the nursery and grow-out phases in *P. fucata*. The present study indicated that the tropical environmental temperature favours growth of the species.

Sagara and Takemura (1960) reported that *P. maxima* reached an average size of 10-16 cm in DVM after two years in the western Australian waters. Reliable data with regard to growth of silver-lip pearl oyster (*P. maxima*) is scarce (Wada, 1953). According to Tipaporn *et al.* (1997), *P. maxima* reached a shell height of 58 mm after 2 years and survival was around 50%. An experiment on rearing of *P. maxima* by Beoton Pearl Co. introduced into Palau waters from north Australia showed that they reached a DVM of 16 cm in 2 years and 21.8 cm in 5 years (Wada, 1953). Considerable spatial and individual variation in growth of *P. maxima* in western Australia was noted and exceptional individuals have been observed as large as 300 mm (DVM) from the Lacepede Islands (Hart and Joll, 2006). In the present study, the growth observed was not uniform, with one fast growing group, a major group of medium growth and a slow growing group of 'runts'. The fast growing group, reached a maximum DVM of 96 mm in 12 months, 128 mm in 18 months and attained a maximum DVM of 141 mm in two years. 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). Pit and Southgate (2002) observed that small spat do not catch up larger individuals within a cohort. In land-based system during the present study, due to accessible provision of optimum environment, high growth and survival was observed.

Rose *et al*. (1990) showed that *P. maxima* is protandrous, maturing as males at one year with a shell height of 110 mm. Present study showed that during the second year (after 18 months) gonad development occurred and matured as males at a mean DVM range of 104-115 mm. Hart and Joll (2006) showed that at 110 mm DVM, the size when males start to mature, their age would be between 2 and 3 years. It was noticed that maturity in *P. maxima* followed similar pattern under land-based culture system indicating that the system is biologically sound with average monthly growth rate of 5.45 mm in DVM and of 3.87 g in weight in the first year and 3.17 mm (DVM) with weight of 8.95 g in second year. These results are in agreement with those reported by Knuckey (1995) as well as that of Rose and Baker (1994).

After a period of 6 months, the increase in TWT was 3.2 g month^{-1} (mean) while from 6 months to one year, it was 4.76 g month^{-1}. The TWT gain showed a continuously increasing trend upto 18 months of growth (11.49 g month^{-1}) which is the maximum rate observed under land-based conditions. From 18 months onwards the increment in TWT was 6.41 g month^{-1} upto 2 years. The TWT for the first year of life cycle was moderate while the increment in TWT almost doubled during second year. It appears that the increments in weight are more perceivable than that of the increments in length at advanced stage of growth.

Survival and growth of pearl oysters recorded under the land-based system was high as compared to those reported in the wild or in open sea farms (Kanauer and Taylor, 2002a, b; Hart and Joll, 2006) which could be attributed to maintenance of optimum water quality parameters, optimum food availability and absence of fouling. This indicated that the system offers a congenial environment for *P. maxima.* According to Syda Rao (2007), *P. fucata* under land-based system survived for more than 6 years and was able to produce larger pearls owing to the availability of large sized oysters. Similarly in the case of *P. maxima*, the present results appear promising for production of large pearls.

It was observed that *P. maxima* attained mean THK of 23 mm at a mean TWT of 100 g while the THK was about 29 mm at 200 g TWT (Fig. 4). The land-based culture system was found to be favourable for the growth of *P. maxima* with regard to morphometric measurements and reduced incidences of deformities as compared to the other culture practices and therefore a population of implantable oysters can be obtained with desired THK and TWT. Gervis and Sims (1992) reported that the first implantation in *P. maxima* was carried out at DVM of 120 mm at the age of 2 years. The fast growing group can be seeded from around 18 months onwards and majority of them have reached operative size by about two years. There is also scope for maintaining silver 'saibo' pool for future use after screening at the age of 20 - 24 months as practiced in Irian Jaya, Indonesia (Kanauer and Taylor, 2002b).

Land-based marine pearl culture is a novel technological concept suitable for all three important species of pearl oysters *i.e., P. fucata, P. margartifera* and *P. maxima* (Syda Rao and Kumar, 2008). Growth rate, among the other factors, is also a very important factor, contributing to the ultimate goal of quality pearl production. The present study indicated that the land-based system appears to be congenial for the growth and for obtaining ideal biometric relationships of *P. maxima* and therefore, it may be possible to maintain a pool of pearl oysters under this system for large size pearl production.

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