CHAPTER 1

GENERAL INTRODUCTION:

1.1. PREAMBLE

Mankind has always been attracted to pearls, the most mesmerizing and noble of gems. The allure of the pearl, the most ancient and most precious of gems, is timeless and universal for humans. The pearl has a history more ancient, more fascinating and more regal than any other gem. In the modern world also, fine pearls continue to evoke a sense of awe and wonder, probably because of our understanding of how the pearl is actually created.

Though the Chinese experimented with pearl cultivation for hundreds of years, it was not until the end of the 19th century that real progress was made. An Australian named William Saville-Kent was the first person to find the technique of taking a piece of mantle tissue from one oyster and implanting it in another. Three Japanese inventors - a biologist named Tokichi Nishikawa, a carpenter named Tatsuhei Mise and the son of a noodle maker, Kokichi Mikimoto perfected the techniques of culturing pearls (Silas, 2003). In the year 1907, Tokichi Kishikawa produced the first spherical cultured pearl in the oysters. Subsequently, the credibility of cultured pearl as jewel was established in the 1920s and was followed by a boom of pearl culture industry with a master touch of Mikimoto and several other industrialists, who joined the bandwagon.

The history of Indian pearl is not very different. Admired throughout the world as the finest of ‘Oriental pearls’, they fetched a price beyond imagination. These pearls had superior lustre and overlay colours under light and were mainly from India. The high value of the Indian pearls made the then British government to appoint special officers extensively for Pearl Fisheries in the Madras Presidency as
well as in the Kingdom of Kathiawar (Gujarat). One such appointee was James Hornell, whose reports speak of pearl fisheries in the Gulf of Mannar in detail. He even attempted to produce cultured pearls in the year 1908.

The technology of pearl production based principally on the Japanese methodology was successfully tried and perfected in the Indian pearl oysters by Dr. K. Alagarsawami of the Central Marine Fisheries Research Institute (CMFRI). Though the technology of pearl oyster farming and pearl production were made available indigenously, supply of pearl oysters from the natural beds became scanty and there were apprehensions that the technology could not be put to use due to the dearth of pearl oysters. This problem was solved timely by a breakthrough in hatchery technology by Dr. Alagarswami and his team in 1981, when they produced pearl oyster spat in the hatchery in large numbers. The development of the technology for the production of seeds in the hatchery was an important milestone achieved by the Institute that helped in enhancing the number of oysters available for nucleus implantation and thereby reducing the dependency on the natural resources. Thus, the CMFRI became the nucleus of pearl culture research and development in India.

Pearls are also obtained from fresh water sources. The culture of fresh water pearls has been developed using the fresh water mussels, Lamellidens marginalis, L. corrianus and Parreysia corrugata (Gopalakrishnan et al., 2003). But their quality is somewhat inferior when compared with the pearls produced by the marine pearl oysters. Production of natural pearls is accidental and rare in occurrence. When a foreign body enters into the body, a pearl sac composed of epithelial cells of the outer mantle is formed and a pearly substance called the nacre is secreted around the foreign body, which forms the pearl. Natural pearls are irregular in shape and are produced either within the mantle, in other soft tissues of the oysters or between the mantle and the interior of the shell. The huge demand of natural pearls led to the over exploitation of oysters for several decades, resulting in the destruction of most of the pearl oyster beds.
In Indian waters, six species of marine pearl oysters have been recorded. They are *Pinctada fucata* (Gould), *P. margaritifera* (Linnaeus), *P. chemnitzi* (Philippi), *P. sugillata* (Reeve) and *P. atropurpurea* (Dunker) (Rao and Rao, 1974). In India, the most widely distributed species is *P. fucata* and this species is extensively utilized for the production of quality pearls. *P. margaritifera* is the other species, which produces black or steel gray pearls. The other four species are not of much importance, as the pearls produced by them are of inferior quality and are not having any economic value.

Though India is endowed with a long coastline, the locations suitable for pearl culture in sea itself are quite limited and consequently entrepreneurs have not shown much interest in pearl culture. The coastline of the mainland is subjected to natural calamities like cyclones and storms, which makes it more expensive for maintaining structures for inshore pearl culture systems. Moreover, the increased level of pollution load in the coastal waters leads to high mortality of oysters. Disease outbreak and predation of oysters are the other constraints. In some areas, heavy silt condition causes the mass mortalities of the oysters.

Therefore, a need for developing an alternative viable and completely safe system for the culture of pearl oysters was felt and an attempt was made to culture the marine pearls in the shore based facilities. For this purpose, it was necessary to develop a comprehensive system for i) production of pearl oyster spat in the hatchery, ii) grow out for the spats to get adults suitable for surgery, iii) surgical implantation of nucleus and iv) maintenance of implanted oysters for a required period to get the quality pearls. CMFRI foraged into this novel concept and developed technology for producing quality pearls in the onshore systems.

Production of quality pearls depends on the health and physiological conditions of the pearl oyster. The external factors such as food supply both in quantity and quality and water quality parameters (salinity, temperature etc.) can
also play important roles in pearl production. Therefore, it is also necessary to have
a clear knowledge about the interactions of the environmental parameters on various
physiological processes such as filtration, oxygen consumption and excretion and
their integration for evaluating the growth, especially in the controlled environment.
Faster growth rate reduces the lengthy grow-out times as well as minimize the
expenditure. Taken together, information on all of these aspects is likely to yield the
most complete understanding for successful rearing of the oysters as well as for the
production of quality pearls.

1.2. THE SPECIES STUDIED

Because of its wide distribution and extensive use in pearl culture operations,
*Pinctada fucata* was considered for the present study. The taxonomical position of
the species is:

*Pinctada fucata* (Gould, 1850)

(PLATE I A and B)

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Mollusca</th>
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<tbody>
<tr>
<td>Class</td>
<td>Bivalvia</td>
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<tr>
<td>Order</td>
<td>Anisomyaria</td>
</tr>
<tr>
<td>Family</td>
<td>Pteridae</td>
</tr>
<tr>
<td>Genus</td>
<td><em>Pinctada</em></td>
</tr>
<tr>
<td>Species</td>
<td><em>fucata</em></td>
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*Perlamater vulgaris* Schumachar 1817

*Avicula fucata* Gould 1850

*Avicula fucata* Reeve 1857

*Pteria (Margaratifera) vulgaris* Jameson 1901

*Margaratifera vulgaris* Hornell 1922

*Pinctada vulgaris* Prashad 1932

*Pteria vulgaris* Gravely 1941

*Pinctada fucata* Hynd 1955

*Pinctada vulgaris* Satyamurthi 1965

*Pinctada fucata* Rao 1970
Pinctada fucata

Plate 1

A. Left Valve: External View

B. Right Valve: External View
1.2.1. Description

The shell is characterized by fairly long hinge; its ratio to the broadest region of the body of the shell is about 0.85 and its ratio to the longest dorso-ventral measurements being 0.76 (Rao and Rao, 1974). The convexity of the valves is greater than in other species of the genus *Pinctada*. There is a well-developed posterior ear and the adductor impression is large and sub-central. The shells are with reddish brown or yellowish brown in colour with radiating rays of lighter colour. There is a well-developed nacreous layer having golden yellow in colour and has a bright metallic lusture. The growth processes are projecting at successive intervals from the external surfaces of the shell at its distal border. The valves are more or less rounded in outline with flattened dorsal edge ending in projecting wings. The left valve is more concave and deeper than the right one.

The soft parts of *P. fucata* consist of viscero-pedal mass covered by right and left mantle lobes, which are fused dorsally, but free anteriorly, posteriorly and ventrally (PLATE II A and B). The mantle edge consists of two thin folds with pigmented papillate edges. The outer fold being parallel to the inner surface of the shell and the inner fold called the pallial veil or velum, projects at right angles from the mantle edges. Muscular and elongated foot is present at the mid position between the mouth and the intestinal lobe. At the proximal end of the foot, there is byssus with the byssus fibres used as the attachment organs to the substratum. The adductor muscles are with white glistening muscle fibres and a broad region of colourless semi translucent fibres. Paired asymmetrical gonads with creamy yellow in colour form the reproductive system. The gonadal follicles cover the stomach and part of intestine. The alimentary canal consists of the mouth, provided with two pairs of labial palps, the oesophagus, the stomach and a coiled intestine. The rectum passes through the pericardium, lies around the posterior aspect of the adductor muscles terminating in the anus.
Plate II

Pinctada fucata

A. Viscera after opening the valves

B. Closer view of the viscera
The pearl oysters can move with the help of the foot over short distances after detaching the byssus threads from the substratum. Pearl oysters are filter feeders. The organic suspended particles contained in seawater are the source of food for them. Minute food particles enter inside the pearl oyster along with the water current passing through the narrow slit formed by the inwardly directed edges of the pallial lobes and they are carried towards the branchiae which act as fine strainers arresting every particles in the water current. The particles are transported to the marginal grooves, the ciliary tracts of which in turn carry the food particles to the mouth via the palps. In turbid seawater, the filaments become chocked disturbing their respiratory activities and stop filtering. The labial palps have the ability to reject unwanted materials like mud particles etc.

The sexes are separate but externally difficult to distinguish them. Fertilization is external following the liberation of spermatozoa and ova. The males initiate the act of spawning followed by the females. The first cleavage occurs after 45 minutes of fertilization. After five hours, the gastrula stage is attained. After seven hours of fertilization, free swimming trochophore larva develops with pre-oral and post-oral tufts of cilia. The veliger stage having a shell is reached after a period of 18 hours of fertilization. Eye spot stage having the measurement 190 X 180 μm is developed on 15th day. The eye spot is prominent at the base of the foot primordium. A foot is developed at pediveliger stage, which is reached on 18th day. The pediveliger is transformed to spat, which settles and attaches itself to the substratum initially by foot but later by byssus threads. Normally, the spat measures 300 μm and settles on 24th day (Alagarswami et al., 1983a; 1983b).

*P. fucata* inhabits at a depth of 10-20 m in the Gulf of Mannar and it is found in the intertidal zone of the Gulf of Kutch region. Thus the species is able to adapt itself to inhabit a wide range of depths. *P. fucata* is stenohaline and prefer high salinities. Turbidity is considered as an important environmental factor for the distribution of *P. fucata* in natural bed. Heavy silt, causing high turbidity not only creates problem for the respiratory activities but also hampers their filtration rate. Of
course, there is a view that turbidity during metamorphosis is desirable for shielding the larvae against ultraviolet radiation.

Natural pearls produced by *P. fucata* are known to be of high quality. The quality of pearls depends on the thickness of nacre, colour, shape and iridescence. The colours of the pearls produced by *P. fucata* are generally golden yellow, ivory white and some are grey (Alagarswami and Qasim 1973). Regarding the cultured pearls, size of the oyster and post-operative care determines the quality (Dharmaraj and Sukumaran, 2003a; 2003b). The cultured pearls are always spherical because of the nuclei implanted are spherical. Colour of the cultured pearls can be modified by dietary and environmental manipulations also (Easterson *et al.*, 2003).

### 1.2.2. Distribution

*P. fucata* is distributed in considerable numbers in Red Sea, Australia, Japan, Indonesia, Venezuelan Islands, China, Korea, Persian Gulf, Western Pacific Ocean and Margarita. In India, this species is distributed in the pearl oyster bed called ‘paars’ in the Gulf of Mannar in the southeast coast of India, extending from Kilakarai to Kanyakumari and at the depth of 7-12 fathoms (Fig. 1). At least 65 numbers of ‘paar’ have been identified in that region. The areas of these natural beds of pearl oysters are extending from a few hectares to several square kilometers. In the north west coast of India, they are sporadically distributed on the intertidal coral reefs (‘khaddas’) in the Gulf of Kutch region. They are found attached to live or dead corals, rocks, molluscan shells, calcareous algae or other hard substratum with byssal threads. Sometimes they are attached with each other forming ‘bunches’. In the littoral waters of the Palk Bay, *P. fucata* occurs sporadically on loose sandy or muddy substratum attached to the submerged objects.
Fig. 1 Distribution of the Pearl oyster beds in the Gulf of Mannar
1.3. SCOPE OF THE PRESENT STUDY

Study of growth is an essential prerequisite for any culturable species more so for the culture of marine pearl oyster, *P. fucata* in controlled environment in the onshore tanks. Growth rates are useful indicators of the fitness of the oysters and a faster growth rate reduces the lengthy grow-out times and thus minimizing the expenditure on culture. Various environmental factors such as temperature, salinity and food availability and synergistic effects from all of these affect growth rate. An experiment was therefore conducted to study the actual growth performances of juveniles of *P. fucata* in onshore tanks for a continuous period of 12 months. For this purpose, two sets of experiments were conducted simultaneously, in the first set of experiment, the pearl oysters were kept in a flow-through system and in the second set, exchange of water was undertaken on alternate days. The experimental data of differential growth between the two systems were analyzed to find out optimal conditions for maximizing the growth in the onshore systems.

Temperature plays a vital role influencing many physiological processes such as filtration, respiration and excretion of the bivalves. On the other hand, animal may show varied physiological responses to changes in salinity like decrease or increase in oxygen uptake, feeding and excretion. The application of physiological energetic methods to bivalves enables us to predict or explain the growth of specimens exposed to known environmental conditions on the basis of their energy balance. Considering this aspect, experiments were conducted with an aim to determine how filtration, ingestion, absorption and respiration are affected in *P. fucata* on exposure to different temperature and salinity regimes. The measurements provide a set of relationship and these results are integrated by means of the energy balance equations. The performance was assessed by means of two physiological indices, such as scope for growth (SFG) and net growth efficiency (*K*₂). SFG is determined by measuring the energy ingested which is available for growth and reproduction by subtracting the amount of energy respired and excreted from the absorbed energy from the food. When SFG is positive, energy was
available for growth and/or reproduction but when this index is negative for a prolonged period of time, the organism must catabolise tissues and ultimately may die. The experimental results provided important information to find out suitable temperature and salinity ranges for their optimum growth in the onshore culture system.

Starvation is a condition where the energy acquired from feeding is not sufficient to balance its basal demand for energy. An experiment was designed to study the respiratory activity by measuring the oxygen uptake during starvation. Standard rate of oxygen consumption refers to the oxygen uptake within an inactive organism and the routine rate of oxygen consumption corresponds to the spontaneous activity during normal feeding. During starvation, the routine rate of oxygen consumption normally declines to its standard level after a period of time. Subsequent feeding by the starved animals results in the rapid increase of oxygen consumption towards the maximum or active level. In this experiment, the different levels of oxygen consumption of *P. fucata* were measured in relation to water temperature. The scope for activity, an index of the energy available for activity and other physiological processes were then calculated in different water temperatures.

Feed dose and feeding frequencies play another important role for the growth of pearl oysters, *P. fucata* in controlled environment. Thus an experiment was conducted to study actual short-term growth performances of the juveniles of *P. fucata* under various concentrations of the mixed micro algae and at different feeding frequencies in order to get the basic idea about the ration level supporting optimum growth for the pearl oyster juveniles in the onshore culture system.

1.4. EARLIER STUDIES

Reviews of the pearl culture works in Japan and elsewhere are found in the works of Cahn (1949), Wada (1973), Mizumoto (1979), Kafuku and Ikenoue (1983)


Chellam (1978) and Yamaguchi and Hasuo (1978) studied the effect of water depth on growth and activity of pearl oysters. Nishi (1961) studied the effects of various factors such as settlement of fouler, low salinity, gonad tissue maturation, suspended solids and current speed etc. on the growth of pearl oysters. Watabe et al. (1957) studied shell formation in young oysters.


Galstoff (1931), Alagaraja (1962) and Alagarswami and Chellam (1977) have studied the length-weight relationship of the pearl oysters.

Growth of pearl oysters have been studied by Herdman (1903), Hornell (1922), Kobayashi (1948), Cahn (1949), Devanesan and Chidambaram (1956),


The effects of water temperature on clearance activity for the pearl oysters have been studied by Uemoto (1968), Itoh (1976), Numaguchi (1994a; 2001). Yukihiro et al., (1998a) studied the dependence of the clearance rate on body sizes of the pearl oysters. Effect of species of microalgal feed and food concentration among pearl oysters was studied by Yukihiro et al., (1999). Methods of measuring filtration in pearl oysters were described by Yamamoto et al., (1996).

The temperature effects on absorption efficiency in the pearl oysters were studied by Yukihiro et al., (2000) and the absorption efficiency related to the size of the bivalves have been studied by Yukihiro et al., (1998a).

The allometric dependence of oxygen consumption on body size of pearl oysters have been studied by Itoh (1976) and Yukihiro et al., (1998a). Yukihiro et al., (2000) recorded the temperature dependence on oxygen consumption.

Itoh (1976) and Yukihiro et al., (1998a) studied the allometric exponents of ammonia excretions in pearl oysters.

The physiological and behavioral response and survival of pearl oysters to change of salinities have been described by Rao and Devaraj (1996), Katada (1958), Ota and Fukushima (1961) and Alagarswami and Victor (1976) and Numaguchi and Tanaka (1986a). Alagarswami and Victor (1976) have studied the effects of lower salinities on the filtration rates of the pearl oysters.

Effect of feed quality and quantity on the growth of the pearl oysters have been documented by Bellanger (1995) and Yukihiira et al., (1998b and 1999).

1.5. PLACE OF THE STUDY

All the experiments were conducted in the Kovalam Field Laboratory of CMFRI. The Field Centre is located on the shore of Bay of Bengal in the village, Kovalam, which is in the Chengalpattu District of the state of Tamil Nadu, India. It is about 40 km away from the Chennai city, the capital of Tamil Nadu (Fig. 2). Kovalam Field Laboratory is supplied with unpolluted seawater from the nearby sea. In Kovalam, the maximum salinity (33.97 ppt) was recorded in the month of July, which declined to its minimum value of 28.02 ppt in January. There was a gradual increase of salinity from January to July and then reduced gradually till the months of December-January. The water temperature showed its maximum value of 31.1°C in the month of June, declined to lowest of 24.6°C in December. The pH value was in the range from 7.4 to 8.0. The ammonia and nitrate contributed very little having
Fig. 2. Map showing the location of Kovalam, where the Kovalam Field Laboratory of Central Marine Fisheries Research Institute is situated.
average values of 0.08 ppm and 0.02 ppm respectively. Dissolved oxygen did not show any definite pattern and varied from 3.48 ml/l to 4.09 ml/l. Constant aeration by diffusing compressed air through air-stones or simply bare end airlines in the tanks provided the dissolved oxygen always in the enhanced level.