General Introduction

(Historical background, A short description of species, Taxonomic position, life cycle of Penaeids, and Genesis of the study)
Sea is a limitless source of protein rich food. In recent years, the food resources of the land are not increasing in proportion with the growth of the human population. Due to acute shortage of protein food, sea is the only alternative remained for exploitation.

Marine ecology comprises the ecology of the world's ocean with their shore and estuaries. Ocean is a treasure house of many living creatures. About 26 phyla of marine organisms are found in the ocean. Arthropods contribute fourfifths of all marine animal species with over 35,000 varieties. Ocean is divided into distinct realms and in each realm, particular type of organisms are found. These organisms are dependent on each other for feeding and shelter in different ways. Individual organism, group of organisms and the ocean environments in which these organisms exist, constitute ecological system and together it is called as an ecosystem (Tansley, 1935). The conceptual unit of ecological science, whether large or small, living or non living or both, possesses individuality, a degree of stability and permanence characteristic functional cycles. Thus ecosystem can be defined as a functional system and included organisms of a natural community together with the environment.
The global harvest of fisheries including those of cultured animals but not seaweed, has increased by 15% during the year 1993. This increased value is due to high demand of protein food for human consumption. Global fisheries demand in the year 2000 is estimated to be 110-120 million tones. Annually about 14 million tones of cultured and captured fisheries are directly used for human consumption. The capture fisheries provide about half of all global consumption. Therefore, capture fisheries are the valuable contributors for human nutrition and health.

India has a coastline of about 7,000 km and an Exclusive Economic Zone (EEZ) of 2.02 million sq. km. Over the last two decades, tremendous increase in fishing activity has been witnessing to exploit the renewable resources from EEZ. However, India has an estimated marine resource potential of 3.9 million tones. The capture fisheries resources have stabilized to around 2.5 million tones (Anonymous, 1992). It has been realized that any further increase in efforts may not yield encouraging returns since the capture fisheries resources have almost reached to the maximum sustainable yield. India's fish and fish products export was 172,000 tones amounting to Rs. 1366 crores during the year 1990-91 (Anonymous, 1992). Indian marine products export has increased by 19.4% by quantity and 6% by value between
1988 and 1990 though there was a sudden fall in the economic growth during these years globally, from 4.5 -3.4%.

Shrimps are one of the most important commodities seen in the global fishery trade. They command a leading position in the world market by virtue of their everlasting demand and competitive international price. Shrimps are at present the most important aquaculture products from the tropics with almost 640,000 tones being farmed world wide in 1993. The major world market for shrimp is located in the temperate region like U.S.A, Europe and Japan.

Shrimps readily fall into the luxury food category because of the apparently insatiable appetite of the major consumers markets. Japan and America together account for more than half the world consumption of shrimps. In addition, there is a growing competition from the European community also. This great demand has substantially increased the fishing effort and encouraged farming activity all over the world.

In the last 15 years, demand for shrimp as well as their price has steadily risen. However, due to increase in price of fuel required for mechanized boats in mid 1970's, the shrimp capture fisheries have become relatively less profitable though shrimp landing from the ocean has increased to approximately
Shrimps form an important component of the marine fisheries of India. Since early 1960, the Indian shrimps have found a place in the export market and currently it is fetching substantial foreign exchange worth almost Rs. 800/- crores initially. India topped the list of leading shrimp producing countries in the world in the late 1970's which attained a maximum production of 0.13 million tones. However, the capture fishery of the marine shrimps has more or less reached to its peak in mid 1980 and occasionally it has shown a downward trend. The Indian contribution to global shrimp production through capture and captive fisheries was around 0.2 million tones which was almost 9% of the total world production. According to the estimates of 1989, Indian shrimp (0.025 million tones) accounted for merely 4.2% of the total global aquacultural shrimp production of 0.59 million tones (Infofish, 1990a; MPEDA, 1986).

The attention has now been turn to cultivate commercially important varieties of fin and shell fishes captivity which otherwise is known as aquaculture. Aquaculture is one of the most rapidly developing sub-sectors
in the world. The farming of fishes and prawn has boost
income of farmer suffering from low agricultural productivity
and fluctuating prices of agricultural products. The total world
aquaculture production for 1985 was 10.2 millions tones. Asia
accounted for 78% (8.0 millions tones) of the aquaculture
production. The countries with highest production rate are;
China, Japan and India with the production ranging to 2.8, 1.2
and 1.1 million tones respectively (FAO/ RAPA, 1988). Total
world aquaculture production by the year 2,000 will be
estimated to 29.3 millions tones. The projections by then will
reach to 2.3 million tones for India and 9.9 million tones for
Asia - Pacific region. China's supremacy in aquaculture
production is unequaled for much of the conventional fish
rearing technologies. Mostly developing countries have low
production through aquaculture even though, U.S.A, Canada
and the Scandinavian countries have lately recognised the
significance of the role of aquaculture not only in improving
economy but also for human health and welfare through
production of health foods. The increasing demand for prawn
and shrimp in the early sixties has triggered the interest of
both government and private sectors in developing prawn
industry all over the world.

Shrimp farming on a commercially scale has been
developed as an important food industry in countries like
Japan, India, Taiwan, Indonesia, Thailand, Malaysia and Philippines. High demand in the International market, growing opportunity in shrimp farming, generation of employment and foreign exchange earnings have encouraged many countries to place high priority on the development of the shrimp culture industry.

Most shrimp culture in developing countries are practiced in the tropics to take advantage of the year round growing season. Ecuador is leading in shrimp production (about 38,000 kg/ha). Other tropical countries like Thailand and Taiwan including Malaysia, Philippines, Panama, Honduras and Brazil are producing shrimp on large scale (Pretto, 1983; Shang, 1983). In these tropical countries, pelleted shrimp rations are available at a very high cost, as such operational cost of shrimp farming has gone up.

Though there is a high demand for shrimp in developing countries, the availability of the shrimp is not adequate to meet the growing demand from both natural fisheries and farms (Garcia and Le Reste, 1981). However, over exploitation of natural fisheries and environmental degradation of shrimp habitats in some countries, even the supply of shrimp larvae (seed), has adversely effected the shrimp production (Provenzano, 1985). The natural oceanic fishery cannot satisfy
world demand for shrimp (Provenzano, 1985). Aquaculture is perhaps the most practical means of increasing shrimp production. This practice requires a sound scientific background to improve nutrition, disease, management and control on reproduction. Crustaceans farming has been practiced since the days of the Pharaohs but in Japan, the modern shrimp farming was not began until 1934 (Schmitt, 1973; Provenzano, 1985). However shrimp farming is now a world wide activity to the extent that farmed shrimp now contribute 30% of the world's total shrimp production (Weidner and Rosenberry, 1992). Shrimp farming has dramatically increased to contribute substantially the total world shrimp catch and in some countries it is estimated to be 50% of the total fish catch (Weidner and Rosenberry, 1992). A considerable growth in shrimp aquaculture has been observed since 1980's. The annual shrimp production was 0.1 million tones in 1980 whereas, it increased to 0.721 million tones in 1992 (Csavas, 1993) and further 0.609 million tones in 1993 (Rosenberry, 1993). This has been attributed to the availability of improved shrimp seedstock and feed quality (Csavas, 1993).

Aquaculture accounted for about 7% of the total world's shrimp supply in 1983. The production has grown to 28% by 1990 and about 50% by 1995 from the aquaculture industry.
The major shrimp producing countries including Asian countries are India, Indonesia, China Taiwan, Thailand and also U.S.A, Mexico, Ecuador and Denmark. In the world shrimp market, there is still a strong ties between Asia, Japan, U.S.A, Central and South America. In the global market shrimp production showed tremendous increase in growth up to nearly 200% over five years from 1984-85 to 1988-89 whereas, the Indian farmed shrimp growth during the same period was around 115% with an average annual growth of 23%. In 1989, India ranked seventh in global prawn culture production. According to 1988 statistics, India ranked 6th in shrimp production (Tan and Cruz, 1988; Infofish 1990b). In 1988-89 shrimp production in India through farming was 0.75% of the country's total fish production and 11.8% of total shrimp production from culture and capture fisheries, Out of 0.2 million tones of Indian shrimp production through capture and culture fisheries, only 28.5% was of high quality and exported for earning foreign exchange while the rest found their way in the local market. The contribution of marine shrimp products were about 45% in quantity and 75% in value for the total marine product exported (Anonymous, 1992). India produced about 50,000 tones of cultured shrimp during 1993 (Asian shrimp News, 1994).
Shrimp farming in India has a strong impact on the utilization of the land and water resources. It provides an excellent employment opportunity and generates enough income to the coastal villagers. There is about 1.4 million ha. of brackish water area available for aquaculture of which 60,000 ha area is under culture whereas, about 122,000 ha area has been identified for immediate utilization for shrimp farming.

Among various crustaceans, the marine shrimps of the family penaeidae constitute the dominant aquaculture group at present. There are about 55 species of penaeid shrimps occurring in the commercially landing centers along the Indian coast, of which nearly 15 species are suitable for aquaculture (Gopalan and Rao, 1981). Among them *Penaeus monodon*, *P. indicus* and *P. merguiensis* have gained more preference because of their larger size attained within a relatively short period and fairly good survival rate in grow out ponds.

In India, shrimp culture has grown into a very lucrative bio-industry, particularly along the east coast, with huge capital investments and high returns. However, due to outbreak of disease very recently and ban on the utilisation of coastal areas have raised doubts over the long terms
sustainability of the industry itself. This is mainly because of the unscientific management practices. Most of the developmental activities are confined along the brackish water bodies with little or no concern for ecology and protection of the surrounding environment. There have been reports of conversion of productive agricultural lands for aquaculture purpose, contamination and salination of ground water sources by the intrusion of brackish water into freshwater aquifers, land subsidence, obstruction to traditional fishing activities, denial of approach to coastal areas and beaches which caused great concern. Some of the visible impacts of the haphazard growth of this industry and mushroom of shrimp farms have been felt directly on the surrounding environment. Therefore, further growth of this industry and sustainable production would largely depend on strict adherence to environmental guidelines.

It is a well established fact that the success of aquaculture depends on the health of the candidate species being cultured. The shrimp diseases caused by environmental factors are correlated to the type of culture system and the water quality management. The extensive, semi-intensive or intensive farming practices require "captive" seawater for farming activities. Shrimp hatcheries or farm are typically intensive or semi intensive in nature. The success of hatchery
or farm depends on the clean and clear seawater which is devoid of suspended materials, competitive organism, disease causing organism and pollution. It is well known fact that in the large bodies of ocean water, physico-chemical properties of the seawater tend to be buffered and balanced. As soon as the seawater is removed from the ocean, the physico-chemical properties of the "captive" seawater are subjected to change and its capacity to support the life tend to decrease. In addition, the increased load of fertilisers, feed and excretory metabolites of the shrimps stocked in the system resulted in changing the water quality to an alarming degree. Low levels of dissolved oxygen, pH, high concentrations of Co₂, ammonia and nitrates are deleterious to shrimp health and impaired growth which also resulted in wide variety of sublethal effects. As such a knowledge of the biotic and abiotic factors affecting the cultivable species of shrimp is a prerequisite for the successful culture. Of the various abiotic factors, the physical and chemical media in which the shrimps thrive have profound influence on the successful breeding, growth and survival of the shrimps.
HISTORICAL BACKGROUND

The history of biological research on shrimps began with Fabricius who published his studies on *Penaeus* in 1798. Later on, the work of Fabricius was compiled and published by Allen and Chin in 1959. Bate (1888) was the first to confirm that shrimps belong to the family penaeidae and classified further into subfamilies and genera (Burkenroad, 1934 a, b; 1936; 1939). The systematic classification of prawns and shrimps was done by several other workers (Kubo, 1949; Racek, 1956; Dall, 1957; Hall, 1962 and Racek and Dall, 1965). These studies lead to a complete classification of family penaeidae. Kishigami (1900) did a detailed study on the prawn of Japan. It was further substantiated by Kubo (1949). In 1956, Kubo has done an elaborate study on prawns of the Indian and Pacific oceans.

The embryological development of prawns passed through nauplius and zoea (protozoea) stages (Muller, 1863). Details of the embryological development of shrimps were available only after 1930 (Hudinaga, 1935, 1942; Heldt, 1938; Pearson, 1939). In Japan, Hudinaga (1942) carried out extensive studies on the fundamental aspects of shrimp culture. After World War II, the commercial importance of
shrimp resources blossomed in USA, India, Australia and Japan. Biological studies of several varieties of prawns and shrimps were studied in Japan by Kubo (1956), Maekawa (1961), Yasuda (1956, 1958), Ikematsu (1963) and others. Oxygen uptake was studied by Maekawa and Otsuka (1955), Egusta (1961) and Rao (1958). The influence of temperature and salinity on growth and survival was studied by Zein-Eldin and Aldrich (1956), Zein-Eldin (1963) and Zein-Eldin and Griffith (1966). Study of shrimp migration and growth under natural conditions was studied by Dawson, 1957; Costello, 1964; and Klima, 1965.
A SHORT DESCRIPTION OF THE PENAEIDS
SYSTEMATIC POSITION

The systematic position of the species up to genus is as follows:

- **Phylum**: Arthropoda
- **Class**: Crustacea
- **Sub class**: Malacostraca
- **Super order**: Eucarida
- **Order**: Decapoda
- **Sub order**: Dendrobranchiata
- **Super family**: Penaeiodea
- **Family**: Penaeidae
- **Genus**: Penaeus
- **Species**: monodon

_Salient features_

*P. monodon* is the largest of the marine penaeid shrimp in the world and it is considered to be the most commercially important species. This species attains a maximum size of 365 mm (440 g weight). The average carapace length of males is
about 37 mm whereas, of females 47 mm. Adult of *P. monodon* is a predator on slow moving benthic macro invertebrates or opportunistic in feeding behavior. The food consists mainly of small crustaceans, molluscs and annelids. Shrimp is relatively eurythermal and euryhaline and can tolerate a wide range of salinity and temperature change. The life span of the species is one and half to two years. Female is reported to live for a longer period than the male. Mating and spawning generally takes place at night. The maximum number of eggs spawned at a time is more than 8,00,000. The life cycles is classified into six phases i.e. embryo, larva, juvenile, adolescent, sub adult and adults.

**Geographical distribution**

*P. monodon* is widely distributed throughout the greater parts of Indo West Pacific regions. The fry, juveniles and adolescents inhabit surface waters such as shore and mangrove estuarine areas while most of the adults inhabit water down to about 160 m deep.

**Common names**

Giant tiger prawn, Sugpo prawn, Green prawn in Taiwan.
LIFE CYCLE OF PENAEID SHRIMPS

The penaeids shrimps complete its life cycle in two different environments; a marine phase during the first stage of development; and secondly an estuarine or brackish phase for postlarvae and juvenile stages.

The spawning occurs in the sea and the egg hatch within few hours, releasing small, simple larvae- the nauplii. The larvae undergo into various larval stages like the protozoea, the mysis and later attain the post larval stage (PL). The larvae are planktonic and swim freely. The late mysis and the early postlarvae stages are passively carried toward the coast and invade inshore, brackish water or estuary where the larvae abandon their planktonic way of life. These larvae then become bottom dwellers, living in shallow littoral areas. In the rich nursery grounds, they grow rapidly and develop into juveniles. As the size of the juvenile increases, they start migrating to deeper water or open estuary to spend their remaining life. (Staples, 1980b; Achuthankutty and Nair, 1983). Soon the shrimps migrate out of the estuary, they continue to grow and become adults (Primavera, 1979) where they attain sexual maturity and start spawning (Fig.1).
GENESIS OF THE PROPOSED STUDY

The tiger shrimp, *P. monodon* is one of the important fishery export commodities in India. High market value and the great demand of penaeid shrimp in the world market provides a strong stimulus for its intensive culture.

There are number of intrinsic and extrinsic factors which affect the normal growth of the shrimps. The important extrinsic factors are salinity, pH, and temperature. However, lack of knowledge of monitoring these factors sometimes lead to heavy mortality in the farmed animal. Considering this important issue, the present investigation was undertaken with the hope that this study work would provide information to understand the effect of various environmental parameters on the growth, survival and other physiological cycles of the juveniles shrimps. This study will also lead to a better understanding of stock fluctuations and useful to develop predictive models to maximize the productivity of shrimps which could be helpful in designing and monitoring more appropriate culture system suitable for commercially important marine shrimps.
Fig. 1: Life cycle of penaeid shrimp (after Primavera, 1979)