CHAPTER 1

Introduction

1.1 Current status of world aquaculture

The proverb “dig the well before you feel thirsty” is used in context when one needs to take the measures before it’s too late. The very proverb seems to be a need of an hour when world’s natural ocean resources for fish are on the verge of decline and at the same time demand for aquaculture products is ever growing. Aquaculture practices can be the “well” to fulfill this, “thirst” of ever-increasing demand of fish food in the world market. Today, there is little doubt about the depleting natural resources. The world community has viewed aquaculture only during last decade and half, as a potential solution to the dilemma of depleted oceans. Furthermore, aquaculture practices have advanced through better management and technological advancement only recently. During this technological advancement, aeration is the most important technique used to maintain the dissolved oxygen concentration of the water. Use of different technological advancement has been studied by many authors (Boyd, 1998; Lee, 1999; Dey et al. 2000). Use of remote water quality logger units for monitoring water quality has been studied by Sreepada et al. (2005).

Mechanized feeding methods have been described by Goddard (1996), and are used mostly in developed countries with intensive practices. It includes demand feeders and automatic feeders, mainly used in Rainbow trout farming. Today we know such advanced farming technologies, as they are in use, mostly, for intensive cultures, however traditionally aquaculture practices are carried out since ancient times. The advent of aquaculture dates back to (2000 B.C). During this period, common freshwater carp *Cyprinus carpio* in China was cultured most commonly. This history of ancient aquaculture practices has been reviewed in detail by Rabanal (1988). The reason aquaculture practices most likely grew in ancient times lies in necessity. In ancient times, foraging and hunting were not sufficient to provide a stable source of food to local communities. Today, however the necessities of past
has changed in to urgencies, in the form of demands, to maximize production and economic profitability it offers. Subsequently, it has raised distressing concerns regarding environment due to intensification of aquaculture practices. According to Hampel (1993) from the mid of the 19th century the global population has almost doubled. Since 1960, it has grown from 3 to 5.9 billion until 1999, and it has been forecasted by Wurts (2000) that, it will attain the growth of 9.3 billion by 2050. Thus, this increase in population has raised and will continue to raise per capita fish consumption along with other aquatic products.

While catering the needs of this ever growing population, global fisheries production has also reached 130.2 million tons in 2001, and has doubled over the last forty years (FAO, 2002). According to Wurts (2000) food fish demand in all countries is expected to increase to 137 million MT by the year 2015. Asia is the major contributor to this production. Of the world total, the China produced 71.2% of the total volume in 2005 and 54.7% of the total value of aquaculture production. According to Crespi (2005), the other nine top producers besides China were India, Indonesia, Japan, Bangladesh, Thailand, Norway, Chile, Vietnam and the United States of America. In 2002, total world aquaculture production was reported to be 51.4 million tones by volume and US $ 60 billion by value (Subasinghe, 2005; Nierentz, 2006).

Apart from the economic aspect, nutritionally fishes and crustaceans are the best source of animal protein we can get. They offer advantage over other animal meat that, they are relatively low in fat. Fish and crustaceans form an important part of the diet for large portion of the people living in developing countries. Many species of fish have heart-protective omega-3 poly unsaturated fatty acids, fat soluble vitamins A, D and E and water soluble vitamin B-complex, minerals such as Ca, P, Fe, I, Se (Subasinghe, 2005), and those species which don't have these nutritional properties still possess an edge over fast food delicacies. These nutritional qualities and our insatiable appetite for delicacies, has contributed for the need to either
exploit fishes from seas or grow them at farms. The demand for top predators such as Swordfish, Tuna has put severe pressure on the existing stocks (Tidwell et al. 2001). USDA statistics show that, the world commercial fishery landings have decreased from 101 million metric tons to 98 MMT in the last three years. Wild catches of shrimp from the world oceans are estimated to have reached a maximum sustainable yield of 1.6 to 2.2 MMT, and future demands for shrimp can be satisfied only through aquaculture production (Agriculture & Rural Development Department, World Bank Report, 2004).

In shrimp culture practices over 30 species are cultured all over the world and amongst all *Penaeus monodon* are the most important cultured species (Paez-Osuna et al. 2001). As many as 230 different species altogether, of algae, mollusks, fish and crustaceans are cultured all over the world indicating the success, this sector has achieved through continuous research and improvement in practices. These practices have shaped up in big industry, providing employment to millions of people (Agriculture & Rural Development Department, World Bank Report, 2004). FAO defines aquaculture as “the farming of aquatic organisms, including fish, mollusks, crustaceans, and aquatic plants.” Farming here implies the intervention in the rearing process, to enhance the production, such as regular stocking, feeding and protection from predators. In 2000, FAO carried out a study on global aquaculture production outlook to evaluate its potential, to meet projected demand for food fish in 2020 and beyond. According to this report, while output from capture fisheries grew at annual average rate of 1.2%, output from aquaculture (excluding aquatic plants) grew at a rate of 9.1% reaching 39.8 million tones in 2002. This rate is also higher than for other animal food producing systems such as terrestrial farmed meat. Much of this aquaculture expansion, as discussed above, has been due to China, whose reported output growth far exceeded the global average production being 69.6% of the total quantity and 51.2% of the total value of aquaculture production (FAO, 2006). According to latest reports, on the current seafood consumption, aquaculture production by 2000 was 32.2% globally, out of which India contributed 35.3%
Hence, aquaculture must continue and accelerate the current trend of supplying the increasing need for fish and seafood products.

1.2 Trends and status of shrimp aquaculture in India

With global demand driving the economies of the fishery and aquaculture dependent population, shrimp aquaculture has emerged as a sunrise sector in India. It started gaining roots only during the late eighties (Krishnan & Brithal, 2002). During the last decade and half, there has been a tremendous increase in annual shrimp production from 35,500 (1990-91) to 97,096 metric tons (1998-99), with an increase in farm area from 65,100 ha to 145,906 ha (Kumaran et al. 2003). India is the fourth largest farmed shrimp-producing nation in the world. The nine maritime states cover about 7000 km of India’s coastline. About 70% of the shrimps are produced on India’s east coast while remaining 30% are produced on the west coast (FAO, 2000). At present, in India, shrimp farming is carried out in about 154,600 ha of brackish water area out of potential 1,190,000 ha (Krishnan & Birthal, 2002).

According to Krishnan and Birthal, (2002) traditional aquaculture has been carried out along the coastal states of India for several centuries. About 50,000 ha of low-lying impoundment (1-10 ha) along bays and tidal rivers are under traditional cultivation and contributes about 25% of the total coastal aquaculture production. Yields from these traditional systems have been reported, to be very low (300-500 kg/ha/y) due to low input levels, limited management and tidally dependent stocking and water exchange. But with global demand luring the traditional farmers to go for more intensive practices, the culture operations quickly progressed from extensive mixed species to intensive mono-species culture of tiger shrimp. Initially it succeeded, but the fact that, most of the coastal states in India were new to commercial-scale shrimp farming at the start of the 1990, the general ignorance of good farming practices, and lack of sustainable extension services, led to host of the problems. The golden period of commercial-scale shrimp culture in India started in 1990 and the bust came in 1994-96 (Hein, 2002), where, an average yield of around
1000 Kg/ha during 1990-94 came crushing down by half to about 400 to 550 Kg/ha in 1995-96 (Kumaran, et al. 2003). Within span of four to five years outbreak of bacterial, viral disease were spread all over. The trend was very much similar, where aquaculture practices got momentum before India; the countries include China, Tiwan, and Malaysia. Poor management practices for water, feed and nutrient use to enhance indigenous productivity during the culture practices in order to obtain better yield were blamed by scientific community and policy makers all over the world.

1.3 Feeding and environmental issues in shrimp culture practices.
New age aquaculture as such started in western world quite early. During 1960 and late 1970s intensive aquaculture practices of Rainbow trout, Atlantic Salmon farming in Europe, Channel Catfish farming in the United States and Kuruma shrimp in Japan stimulated considerable R&D activity in fields of shrimp nutrition (Goddard,1996). Before 1968, for Penaeus monodon culture, no feed was given other than naturally occurring pond biota. It was in 1979, when nutritional data on Marsupenaeus japonicus was prepared, based on the formulations of feed for channel catfish in USA. With worldwide culture of P. monodon for its fast growing and robust qualities nutrient requirements were studied only in 1990s (Shiau, 2001).

Penaeid shrimp are known to ingest a variety of food items i.e. detrital aggregates, animal and plant matter in their natural habitat, and have been described to be opportunistic omnivorous scavengers by many authors (Dall, 1968; Chong & Sasekumar, 1981). The detail shrimp feeding habits and feeding behavior is reviewed in Chapter 2; Section 2.3. In commercial hatcheries, nurseries and grow out ponds, penaeid shrimp larvae require a series of live microalgal species such as Skeletonema, Chaetoceros, Tetraselmis and brine shrimp naupli (Artemia) and artificial feeds. However, in grow out systems dry formulated feed is more important. With the advent of 'Factory Farming' practices especially, intensive aquaculture practices, use of the fertilizers and liming to enhance the indigenous productivity is carried out. Natural productivity is utilized by shrimp initially,
thereafter farmers use artificial feeds. These commercial formulated feeds are nutritionally complete. With multinational companies having great desire to capture the rising market of shrimp culture, endowed extensive research, and came up with the feeds, having higher nutrient manifestations to fulfill the nutritional and energy needs of the farmed animals were proliferated, in the last decade in India. Main reason to adapt these feeds by farmers is the growth achieved by shrimp in the stipulated time period.

In the market driven culture practices with cut throat competition for selling their products in time, and with exporters being munificent by offering competitive prices, due to great global demand to export farmed shrimps, intensification of these practices was inevitable. Another reason in this success story of the filleted feed lies in its maneuverability, as these feeds were easy to handle, apply and store. However, the unscientific ways and irrational feed applications were found to critically burden the aquatic systems, and contributed to high organic loads. Craig et al. (2002) has stated that, even with careful management of feed, about 40 to 60% of feed ends up in the waste. Out of 100 units of feed fed, typically about 10 units of feed are uneaten, and 10 units of solid and 30 units of liquid waste constitute 50%, and are produced by cultured species. Of the remaining 50% feed, only 25% is used for the growth, and another 25% is used for metabolism, and these percentages, vary with species, size, activity and other environmental conditions. Ultimately through experiences, observations and experimentations, it was noticed that only 40% of the feed is consumed and 60% is accumulated at the bottom and contributed to form organic matter. The water with high organic matter and nutrient load can pose great threat to the adjacent natural environments, and may alter the eco-biology of the natural habitat, such as creeks, and inhabitant mangrove foliage. Trott et al. (2004) has shown that, rate of supply of C and N from the shrimp farm exceeds the rates of in situ removal by biological uptake and transformation processes within the creek water and sediment. It is the natural biota right from phytoplankton to fish, which consumes these sources of C and N. This shows the complicated interdependence,
and role played by the organisms residing in these natural environments to utilize these nutrients. The poor water quality of effluent from artificial environments such as the aquaculture pond thus, may alter their functioning.

The harvesting practices discharges large volume of eutrophicated bottom water with highest pollutant loads, and thus pose threat to the residing biota in these environments. Due to higher fish, crustacean densities and due to their constant mobility brings about the sediment disturbances in natural environment. The accumulated food and feces from these animals, lead to high organic carbon accumulation, which necessitate higher oxygen demands for its degradation leading to anoxic to eutrophicated waters (Lin et al. 2001). In presence of insufficient oxygen in reducing environment, toxicants like ammonia, nitrite and sulphide concentrations were also found to be lethal to the aquatic organisms not only to cultured organisms, which depend on the natural water, but also to the one who resides in the natural environment such as creek. Beardmore (1997) has stressed the need to maintain the reasonable effective population sizes in natural populations and the relative scale of population sizes of farmed and wild species.

Further, Beardmore (1997) has cited reports on environmental stress, which indicates that, environmental stress affects the organisms residing in the natural habitat. He has also indicated through his study that, hydrocarbons and insecticides are mutagenic, and these substances, bring about mutation in the sensitive species. The effluents increase the biodiversity of pathogenic bacteria and pesticides accumulate in diatoms, phaeophytes and copepods. They become carriers for diseases and cause bacterial infections. Toxic diatomaceous and crustaceans as food organisms for cultured species reach via water intake to culture practices again. These, and other such kind of practices forming nutrient rich effluents, ultimately are known to critically overload systems and brought hyper productivity of the culture systems and led to sequence of problems like eutrophication discussed earlier. With lack of in depth knowledge in most of the cases by non learned farmers, as well as
limited area available for farm with almost all the ponds used for culture, the farmers were found lack the approach and vision for proper disposal of the aquaculture effluents (Latt, 2002). This ultimately led to deterioration in water quality of pond as well as source water. As mentioned above, the same receiving waters often serve as intake water for neighboring farms and thus, provide the means to spread water-born disease agents from one farm to another (Paez-Osuna, 2001). This leads to spread of disease, frequent outbreaks of viral, bacterial, fungal, disease, which caused huge losses to the farmers in the 1990 to 1995 (Tacon and Forster, 2003). Therefore, with many flaws in management of aquaculture practices, feeding of shrimp culture practices were mainly blamed for the deterioration of the water quality, and subsequently environmental quality degradation. Such consequences raised serious concerns amongst farmers, scientific community and social activist for the better management of the aquaculture practices and rose to very concept of, “sustainable aquaculture”. World Health Organization (WHO) defines the sustainability as, “the development that meets the needs of the present without compromising the ability to meet their own needs.” This relates to continuity of economic, social, institutional and environmental aspects of human society as well as the non-human environment. The guidelines for sustainable aquaculture and aquaculture effluent management at farm level have been described by Boyd (2003).

In 1996, Honorable Supreme Court of India (SCI) in response to petition (No. 561/1994) as based on the reports of Algarswamy (1995) and on the basis of National Environmental Engineering Research Institute (NEERI, 1995) reports, described the development and the external impacts of shrimp aquaculture. The judgment indicated that, the social and economic costs related to the development of aquaculture sector were substantially higher than the revenues generated. For small farmers in the trade, the ratio of investments and revenues generated were inadequate to improve the economic status of the farmer. Thus, socio-economical and simultaneous concerns regarding environment and its social implications ultimately resulted in framing some stringent norms and direction by Supreme Court of India.
(SCI). In its December 1996 judgment, SCI extended enforcement to early 1990 CRZ act, and restrictions were applied to extensive, semi-intensive and intensive shrimp farming to carry out aquaculture practices in sustainable manner. The ordains for the same has been reviewed by Hein (2002). Further, the Hon. SCI (1999), while assessing the environmental impacts caused by pond-based shrimp culture, recommended that, traditional aquaculture should be upgraded using appropriate technology that could result in minimum environmental changes.

The Government of India has also been promoting traditional aquaculture with necessary improvements. However, very little information is available on the environment and production capabilities of modified extensive aquaculture systems in India. As, site-specific reports are available, no serious efforts have been made to study the population structure, recruitment patterns, growth dynamics and sustainability of the systems, nor has been, considered the practicalities of involving rural coastal communities in enhanced production approaches. India as against other countries struggles against major constraints, prohibiting a sustainable development of the shrimp farming industry. It was therefore most important to develop code of best management practices and strategies for enhancement of the utilization of the coastal belt around India for sustainable aquaculture. And in this view present study is important.

1.4 Need for present research

After the consequences of aquaculture practices on the environment many research initiatives until now have focused on the general health management of the shrimp, which aimed to improve disease resistance capacity of shrimp. The introduction of modern tools such as polymerase chain reaction (PCR) for detection of WSSV and other protocols relating to chlorination, pond treatment, cleanliness and modern management techniques such as bio-remediation through various enzymes and probiotics proved to be useful and their use became widespread. However, not much effort have been made to understand the culture systems in an integrated way, in
view, to utilize the indigenous productivity to utilize resources in better manner and reduce the dependencies on external sources for feed and nutrient for cultured species.

It has been documented by Goddard (1996) that, there is very less distinction between semi intensive and intensive production methods in shrimp farming than in fish farming, as natural food organisms play less significant role in both the systems. Overall feeding dynamics are poorly understood especially in shrimp culture practices. It is known that, growth and health of shrimp are primarily dependent upon an adequate supply of nutrient, which generally includes protein, lipid, amino acid and water-soluble vitamins both in terms of quantity and quality (Goddard, 1996). Information concerning the nutritional requirements of many of the cultivated species is well established, however, most has been generated from laboratory based controlled feeding trials, and hence, such information is useful mainly for the formulation or production of nutritionally complete feeds for culture systems (Hasan, 2000). A Large portion of aquaculture in many developing countries is carried out in rural areas, where farmers practice extensive or modified extensive farming methods, as described previously in Section 1.2. In these cases such data on nutritionally complete formulated diets may be less applicable to farming condition where nutrition is from natural food supplies or supplemental artificial feeds.

Experiments involving the use of stable carbon isotopes have shown that 60-70% of shrimp growth in even semi-intensive systems resulted from the consumption of natural food organisms, while formulated feeds accounted for the remaining 30-40% (Anderson et al. 1987). This still holds true for the modified extensive prawn farming practiced in developing countries like India and East Asian countries. Hence, it can be speculated that, when natural fauna play such an important role in intensive and semi-intensive farming practices, which completely dependent on artificial feeds, certainly modified extensive farming practices are more dependent on natural feed. Further, this method involves lower stoking densities (8-10 PL.m\(^{-2}\))
and use of artificial feed with typical FCRs ranging from 1:1.2 to 1:5. With two-crop system per year, such practices over the couple of production cycles can deplete natural food resources. From previous reports (Ruello, 1973; Bell & Coull, 1978; Hedqvist-Johnson & Andre, 1991; Nuns & Parsons, 2000) it is evident that prawns do feed on the natural benthic fauna. Studies by Geoff et al. (1995) indicate that, faunal composition of prepared and controlled ponds were high and prawns also grew faster in such environments. Further, from direct observations (Ingole, 1992) it is speculated that, natural benthic fauna may play an important role in providing diverse food source compared to formulated feed. This natural food may have role in enhancing the overall health and improved immunity with the enhanced disease resistance capacity. In this view, it is important to study the role of natural food in shrimp nutrition.

Comprehensive information about benthic communities from different ecosystems is available, ranging from mangrove ecosystem (Alongi, 1990), Seagrass beds (Walters & Bell, 1986), sandy beaches (Ansari & Ingole, 1983), coralline beaches (Ingole et al. 1998), estuarine mudflats (Ansari et al. 2001) continental shelves and continental slopes (Gremare, 2002), deep sea meio and macrofauna (Ingole et al. 2001;2002). Importance of meiofauna in food chain of benthic environment has been studied by (Gerlach, 1971). Organic matter, bacteria and their extra-cellular products, protozoa and diatoms form a good source of food for benthic in-fauna (Bott, 1999). Influence of physico-chemical properties of soil and water alters distribution of benthic infauna and has been documented (Harkantra & Parulekar, 1989; Smith, 1996). More extensive review of macro-, meio- and microbenthos however has been made in Chapter 2, Section 2.2.

Dissolved oxygen content of the water is one of the most important parameters of water quality. It is a vital factor for all the aquatic organisms having an aerobic type of respiration. To improve the dissolved oxygen concentration and overall water quality, different types of artificial aerators are in use and are reviewed
by Boyd (2003). The artificial aerators help in increasing the oxygen content of all or part of the pond water to certain extent, which ensure the oxygen supply to the shrimp without limiting production at a given management level. Paddle wheel aerators in improving the shrimp growth, and production has been studied earlier by Wyban et al. (1989). The oxygen-transfer rate by using aerator in brackish water aquaculture pond was studied by Rogers et al. (1991). In all 15 important key water and soil quality parameters such as temperature, salinity, pH, Eh, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nutrients (NO₃-N, NO₂-N, PO₄-P and NH₃-N), Particulate (POC) and sediment organic carbon (OC), H₂S, Chlorophyll-a and phaeophytin and their roles has been reviewed in Chapter 2, Section 2.1. However, there is paucity of information on the role, played by artificial aeration in development of bottom fauna from shrimp culture ponds as well as their role in the modified extensive shrimp culture systems, which is practiced by most shrimp farmers in India. With advent of new aeration technology (HOBAS) it was worthwhile to study the effect of artificial aeration on the development of benthic biota (macro- meio- and microbenthos) which can be the main source of natural diet for candidate shrimp species under culture system. Present study in the view, was carried out at the NIO Field Station at Kumta (Uttar Kannad District), Karnataka, India, under the Indo-Norwegian joint research Project entitled “Environmental Management Strategy for Prawn Aquaculture” during 2004-2006. Description of study area and sampling strategies in detail are described in Chapter 3, Section 3.1.