ECONOMIC ANALYSIS OF EXTERNALITIES IN COASTAL MARICULTURE

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I hereby declare that the thesis entitled "**ECONOMIC ANALYSIS OF EXTERNALITIES IN COASTAL MARICULTURE**" is an authentic record of the work done by me and that no part thereof has been presented for the award of any degree, diploma, associateship, fellowship or any other similar title.

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सारांश

नई प्रौद्योगिकियों के स्वीकरण और परिणामी प्रचार में उनके हित-लाभ और अप्रत्याशित बाह्य विशेषताएं (externalities) का सीधा संबंध है. विनिर्दिष्ट स्थानों में पर्यावरण अनुकूल उद्यम शुरू करने केलिए ऐसी बाहरी विशेषताओं का अन्तरीकरण (internalisation) अनिवार्य लगता है. देश में जलकृषि हाल ही में विकसित हुई है. यद्यपि जलकृषि मूलतः झींगा पालन पर सकेंद्रित है तथापि तटीय मेखलाओं में झींगा (*पेनिअस मोनोडॉन* और *पेनिअस इंडिकस*), पंक केकडा (*सिल्ला सेराटा*), कई प्रकार की पख मछली, खाद्य शुक्ति (*क्रासोस्ट्रिआ मद्रासेनसिस*), हरित शंबु (*पेर्ना विरिडिस*) आदि समुद्री जीवों के पालन होते हैं. अध्ययन में तटीय जलकृषि से उत्पादन प्रणाली में होनेवाला लाभ-नष्ट संबंधी एक्स्टेर्नालिटीस पर तुलनात्मक अध्ययन चलाया गया. जलकृषि में होनेवाला प्रदूषण और रोग संक्रमण अध्ययन के विषय बने विपरीत एक्सेर्नालिटीस है. केरल के कोल्लम, आलप्पुषा, एर्नाकुलम, और कासरगोड में स्थित चुने गए 208 जलकृषि खेतों में यह अध्ययन चलाया था. पानी प्रदूषण पर किए फुटकर मूल्यांकन अध्ययन ने व्यक्त किया कि इस पर सुझाए गए वैकल्पिक रीतियाँ स्वीकार करने को पणधारियों में आधा भाग सहमत हुए. भूमि और पानी विश्लेषण पर चलाए अध्ययन ने व्यक्त किया कि पानी की गुणवत्ता भूमि का दाम बढाने का महत्वपूर्ण घटक है. वर्ष 2001-2002 के दौरान झींगा रोग *वाइट स्पॉट डिसीस* के प्रादुर्भाव से हुए वार्षिक नष्ट 1,742.4 करोड रुपये थे, अध्ययन ने साबित किया. बहुमुख तटीय जलकृषि के अनुवर्तन से प्रत्याशित रोज़गार और आय भी अध्ययन का विषय रहा. इसी प्रकार वाणिज्यक हैचरियों की स्थापना, विपणन मार्ग, संसाधन, भंडार सुविधा और नीति निर्देशों के अभाव जलकृषि विकास की सीमाएं आँकी गई.

ABSTRACT

Adoption of any techno-intervention and consequent spread of developmental programmes greatly depend on their direct benefits and externalities. Assessing the extent of externalities and the possibility of internalising them are very essential for identifying and promoting location specific, eco-friendly enterprises. The growth and development of scientific aquaculture in the country is of recent origin although is highly skewed towards shrimp culture. The diversified coastal aquaculture/ mariculture practices adopted in the country are different culture systems of shrimp (*Penaeus monodon* and *Penaeus indicus*), mud crab (*Scylla serrata*), various species of fin fishes, edible oyster (*Crassostrea madrasensis*) and green mussel (*Perna viridis*). The present study aims to bring out the externalities of coastal aquaculture in terms of comparative economic benefits and losses in different production systems. The negative externalities focussed are mainly pollution and wide spread disease occurrence on coastal aquaculture systems. The study was undertaken in 208 farms practicing different types of aquaculture selected from Kollam, Alappuzha, Ernakulam and Kasargod districts of Kerala state during the period 2001-03. The contingent valuation method adopted revealed that the stake holders willing to pay for the development of compensatory mechanism was evenly distributed. Hedonic analysis applied to assess the impact of pollution indicated the influence of water quality characteristics on land value. The study could authenticately project the annual economic loss due to the wide spread occurrence of white spot virus for the country as a whole during 2001-02 as Rs. 1,742.4 crores. The immense potentialities of diversified coastal mariculture practices and their projected income and employment generating potential have been thoroughly analysed and discussed. The constraints such as lack of commercial hatchery, proper marketing channels, processing and storage facility and policy recommendations for optimising the productivity and profitability of various aquaculture practices are given.

INTRODUCTION

1. INTRODUCTION

Aquaculture production from India in 2000 was 2,095 thousand tonnes, worth US$ 2,166 million. The total shrimp exports from India during 2001-02 was 1,27,656 MT worth Rs. 4,132 crores. The cultured shrimp production during 2001-02 was 1, 27,170 MT in which 74, 826 MT was exported fetching Rs. 3,645 crore. The cultured shrimp contributed about 60% in terms of quantity and about 86% in value of the total shrimp exports during 2001-02 (Vasudevappa and Seenappa, 2002).

The growing demand for shrimp in the international market coupled with lucrative price prompted more and more farmers to venture into shrimp farming. The increase in area under shrimp culture and improvement in technology adopted led to the increase in shrimp production over the years. Besides earning valuable foreign exchange, aquaculture satisfies many other national priorities like productive utilisation of waste land, effective rural development and employment generation.

Expansion and intensification of aquaculture has brought along with it a number of environmental and social problems. Aquaculture has been blamed for mangrove destruction, salinisation of agricultural lands and drinking water, conversion of agricultural land, indiscriminate destruction of fry of wild fish and crustacean species, pollution, ecological disturbances, multi-user conflicts etc. Another major set back that the aquaculture, primarily shrimp culture, suffered was the disease outbreak.

Extraneous factors like pollution, disease occurrence and habitat degradation are all found to affect aquaculture. Shrimp farms are largely located in the neighbourhood of agricultural lands or in the drainage basin of water shed areas. Coastal waters especially in major cities are under the threat of sewage pollution. Domestic and industrial pollution also pose a threat to aquaculture. Brackish water canals and creeks being common property resources, their management aspects are usually neglected. Inlet and outlet of the farms on either side into the same waterways is a common practice leading to environmental degradation. The main effects of water pollution on the culture organisms are high mortality rate, reduced growth, slow maturation rate and reduction in the quality and export value of products. Above all polluted environment make the culture organisms more susceptible to disease attacks.

Shrimp farming being one of the activities within the coastal environment, its operations will have direct or indirect effects on the marine ecosystem and other resource based economic sectors operating in the area. Negative environmental effects of shrimp farming and the mistakes committed in the development process receive wide publicity. Not much is done to inform the general public about the positive aspects of shrimp farming or about the shared responsibilities for environmental damages with other sectors of the economy.

Aquaculturists have an economic interest in assuring that the environment, in particular the aquatic environment is appropriate for their culture operations and generate as large an economic surplus as possible. For them deterioration in the environment usually means a deterioration in their net earnings from the culture operations. Enterprises like aquaculture incurring some form of unaccounted external cost would surely find trouble in future. If it is social or environmental costs, the sustainability of the enterprise is at stake. In course of time, the accumulated unaccounted costs would precipitate a variety of problems threatening the sustainability of the system. Such unaccounted costs should be taken care of either by compensating the farmer for his loss or by preventing or cutting down on the externality involved.

Accurate and up to date information is needed to provide the scientific basis of coastal environment management. Strengthening of existing knowledge to quantify the effects of aquaculture inputs on the environment and updating the socio-economic and environmental cost of coastal shrimp farming is imperative. The social and ecological impacts of coastal aquaculture hitherto considered externalities should be internalised in the final valuation of aquaculture products to assess the true costs of producing them. Though it is difficult to calculate the pollution and social costs, it is at least realised that in the long run, these costs have to be worked out, as we work out the imputed costs for an industry, so that correct profits could be taken into account after all the costs are deducted.

Shrimp farming should be developed within the overall framework of coastal area management. Development of coastal area requires a multisectorial, integrated and holistic approach to ensure wise and judicial use of scarce common property resources. It is widely recognised that the major problems in shrimp farming are essentially due to the unregulated growth of the farming sector and hence the system as such cannot be blamed. There are evidences from several other countries that shrimp farming is sustainable both economically and ecologically.

The concept of sustainable development has gained importance all over the world since the Rio Earth summit in 1992. This is the natural consequence of the desire to alter the tangential direction of the present day developments in relation to the environment. Sustainable development has been defined as the management and conservation of natural resources base and the orientation of technological and institutional factors to ensure the attainment and continued satisfaction of human needs for the present and future generations. Such a development conserves land, water, genetic bio-resources; is environmentally non-degrading, technologically sound, economically viable and socially acceptable. Entrepreneurs generally strive to maximise yield per unit area in order to obtain the highest and most rapid return on investment (ROI). The goal is not always achieved due to ecological and economic risks that are involved. A sustainable aquaculture could only provide a sustainable and stable return.

Coastal aquaculture in India is more or less confined to shrimp culture. There is enough scope for diversification with other cultivable species like mud crabs, fin fishes, oysters and mussels. Potential areas, which are still unexploited, offer tremendous scope for these mariculture activities. Low cost user-friendly bivalve mariculture practices provide seasonal vocation for the rural folk. Polyculture of different compatible species also offer a viable alternative to shrimp farming. They require less inputs compared to shrimp culture and are economically viable. Hence promotion of location oriented, resource specific mariculture is ideal for maintaining sustainable production without endangering the existing environmental equilibrium of natural resources.

Natural resources perform a large number of environmental services and ecological functions that a society enjoys. The value of natural resources is not generally revealed because of the situation of missing market. The valuation of natural resources is essential to understand and appreciate its alternatives and alternative uses. The government may like to use the valuation of natural resources as against the restricted, administered or operating market prices for designing natural resources management and conservation programmes.

In India, attempts to estimate economic values of natural resources have been substantial by now. Though it got started with forest based resources, the arena has moved to wetlands, water bodies, wild life, marine life, minerals, pollution etc. There are several methods for the evaluation of environmental costs like hedonic pricing method, contingent valuation (CV) method, travel cost method, productivity method, aver-def expenditure method etc.

A good number of studies attempted to value forest benefits and services mostly using CV method and travel cost method. Many attempts have been made to value various watershed benefits using reduced or changed cost of alternative technologies, replacement cost approach, opportunity cost, productivity approaches etc. CV method was used to evaluate water pollution in river Ganga. Cost-benefit model was employed to estimate pollution abatement costs of tannery pollution in Tamil Nadu.

The social costs and benefits also should be taken into consideration for deciding the advisability of any investment option. Enterprises running on simple economic profit but hampering the social welfare will never be recommended for public or private investment. Aquaculture in India is mostly confined into the landward coastal zone although enough potential is there for the growth and development of mariculture in open waters. Further, in spite of the availability of alternative production systems with different varieties, only shrimp oriented aquaculture has witnessed tremendous development. Price difference served as the most lucrative attraction rather than the usual parameters like site suitability, cost of production or comparative economic advantage. Reaping quick money or profit led to the lopsided development of shrimp oriented aquaculture in certain regions without considering the externalities or sustainability of production. Hence the present study is undertaken focussing with the following specific objectives.

- To assess the externalities of coastal shrimp culture with specific reference to pollution and mangrove destruction

- To analyse the factor productivity and cost and earnings of different aquaculture practices
- To evaluate the comparative economic advantages of different aquaculture practices through a set of key economic indicators
- To assess the economic loss due to the wide spread disease problems of shrimp farming projecting the production potential of developing alternative farming systems

The costs and earnings of different coastal mariculture practices in Kerala are assessed. Different culture systems of marine organisms like shrimp (*Penaeus monodon*, *Penaeus indicus*), mud crab (*Scylla serrata*), Indian back water oyster (*Crassostrea madrasensis*), green mussel (*Perna viridis*) and fishes like milkfish (*Chanos chanos*), grey mullet (*Mugil cephalus*), other mullets (*Liza sp.*), and Asian sea bass (*Lates calcarifer*) in coastal environment are considered for the study. The present study on coastal mariculture practices was limited to the state of Kerala.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1. Aquaculture Practices

In olden days culture practices were limited to trapping and holding operations where wild fry was lured to the pond and it was held there for some time before the harvest. Not much care was given in feeding the organism or in managing the pond environment. Today aquaculture has evolved to such an extent where the cultured species is thoroughly studied to understand its physiology, reproductive biology, feeding and breeding habits, disease resistance etc. Artificial feeds, growth promoters, probiotics, immunostimulants have all been applied to cultured organisms to augment production. Aerators have replaced old water exchange systems. Pond environment is manipulated using chemicals to suit the species cultured.

2.1.1. Shrimp aquaculture

Shrimp aquaculture traces its origin to the brackish water and marine ponds of Mediterranean area and the South- East Asian countries where for centuries farmers raised incidental crops of wild shrimps in tidal fish ponds (Ling, 1977). For hundreds of years shrimp farming had only been considered a secondary crop in traditional fish farming practices in many Asian countries. For most part of the world, especially in Asian countries, shrimp farming expanded and flourished taking advantage of the biological attribute of the shrimp to migrate to estuarine environment after completing metamorphosis to raise young shrimps in brackish water system (Boyd and Clay, 1998).

Modern shrimp farming actually began in 1930s when M. Fujinaga achieved success in spawning and larval rearing of kuruma shrimp, *Penaeus japonicus* (Hudinaga, 1935). In 1960, the first commercial farm was built in Seto Inland Sea of Japan. Commercial grow-out attempts were made in Ecuador in 1960s. This was started accidentally when a broken dyke on a banana farm allowed shrimp to enter and by the time the farmer repaired the dyke, a crop of shrimp had been produced. In United States of America (U.S.A.) commercial shrimp grow-out attempts started in the late 1960s and early 1970s. Shrimp culture practices vary widely throughout the world but have tended to evolve in line with each country's respective resource endowment. Shrimp farming methods in different parts of the world have been reviewed by many authors in detail (Pillay, 1990; Lester, 1992; Liao and Chao, 1993).

The shrimp farming practices were classified by different authors in different ways (Fast, 1992; Liao and Chao, 1993; Sukumaran *et al.*, 1993; Purushan, 1995; Alagarswami, 1995; Rosenberry, 1996; Rao and Ravichandran, 2001). About 60-90% of the shrimp farms in Ecuador, Bangladesh, Indonesia, Vietnam and India are of extensive type. Semi-intensive farming is practiced in 50-90% of the total shrimp farms in Mexico, Peru, U.S and Malaysia while intensive farming predominates (70-80%) in Australia, Thailand and Sri Lanka (Rosenberry, 1996). According to New and Csavas (1993) the bulk of finfish and crustacean aquaculture production in Asia is realized in semi-intensive pond farming systems. The most technologically advanced culture systems are intensive and well developed in countries like Japan, Taiwan and U.S where wild post larvae (PL) are not readily available and where land and labour are expensive.

In India, traditional culture practices include paddy field prawn filtration process of Kerala (*Chemmeenkettu*), the prawn and fish culture (*Bhasabhadha*) in *bheries* of West Bengal, prawn filtration in *Khar* lands of Karnataka and *Khazan* fields of Goa. Alagarswami (1995) and Rao and Ravichandran (2001) reviewed comprehensively the shrimp culture practices currently in vogue in different maritime states of India.

Shrimp culture in India had its origin in Nellore district, Andhra Pradesh, in 1978 at Duggarajapatnam in a two ha water area (Rao and Krishnan, 2001). Commercial scale shrimp farming using semi-intensive methods started only in the late 1980s and early 1990s with setting up of large ventures in the coastal region of Andhra Pradesh and Tamil Nadu. About 11, 90,000 ha along the Indian coastline were found suitable for shrimp culture (Rao and Ravichandran, 2001). About 1,56,500 ha were covered by tiger shrimp culture and shrimp production increased from 1,13,700 MT in 2000-01 to 1,27,170 MT by 2001-02 (Anon, 2002a).

Kerala has a total area of 12,986.6 ha under traditional farming system of which, 10,937 ha are seasonal fields and 2,049.6 ha are perennial fields (CIBA, 2002). A production of 5,540 MT has been reported from 14, 700 ha under tiger shrimp production in Kerala by the year ended March, 2002 (Anon, 2002a). Shrimp farming has been an age-old practice in coastal districts of Kerala; of which Ernakulam district alone accounts for 81.6% of the total traditional shrimp culture area of the state. The traditional shrimp farming practices are of two types: perennial fields where shrimp culture is practiced throughout the year and seasonal fields where paddy (*pokkali*) is cultivated during monsoon and shrimp during post monsoon months (Alagarswami, 1995; Purushan, 1996; Chandramohan *et al.,* 1999; Unnithan, 2000 and Purushan, 2003) have described the traditional system of prawn filtration in Kerala. In recent years interest is being shown to improve the traditional system with selective stocking of desired species like *P.monodon* and *P.indicus.*

Traditional paddy cum prawn filtration practice followed in Kerala has been described as advantageous, economic, proper, stable and correct method of farming, having significance even in the present era (Purushan, 1996). Chandramohan *et al.* (1999) have described the system as an ecofriendly, economically viable and sustainable enterprise, compatible with the ecosystem where efficient land utilisation was possible with rice and shrimp grown in rotation. The shrimp, fishes and rice harvested from the *pokkali* ecosystem played a significant role in addressing the food security problem and poverty alleviation amongst the rural population living along the coast (Purushan, 2003). The traditional system does not involve fertilisation of field, selective stocking, supplementary feeding with compounded feed, predation control and provision for sufficient time to grow (Purushan, 2003). Predation by birds, invasion by clams etc. in traditional prawn fields have been discussed by Nasser and Noble (1992).

Scientific shrimp farming effectively utilised the coastal wastelands in the states like Andhra Pradesh, Tamil Nadu, Gujarat, Maharashtra etc. for shrimp farming activities which ultimately resulted in poverty alleviation and contributed substantially to the rural development in the country (Ponnusamy *et al.*, 2000). Rajalakshmi (2003) has listed employment generation, improvement of living standards and better infrastructure in rural areas, increased revenue to government as the positive impacts of aquaculture. Aquaculture development has resulted in the generation of backward linkages wherein infrastructure facilities like electricity, roads, drinking water, ancillary industries have come into being (Rao and Krishnan, 2001; Kumaran *et al.*, 2003). Processing plants, ice plants, cold storages, hatcheries, feed mills have all come up with scientific shrimp farming which generated employment and income in rural areas.

One of the major problems that shrimp farming faced was the outbreak of diseases (Ponnusamy *et al.*, 2000). Others included lack of proper financial support from banking institutions, lack of proper laboratory facilities in the vicinity of farms for testing disease symptoms, soil and water quality and price fluctuations of shrimp in the international market.

2.1.2. Crab farming

Mud crab *Scylla serrata* has long been an incidental product of brackishwater pond culture in South-east Asian countries (Bardach *et al.,* 1972). Some farmers in Philippines and Bangladesh used to consider mud crab as a nuisance in their shrimp ponds because of their burrowing habit which causes extensive damage to pond dykes (Ahmed, 1992). The traditional crab farming practices existed in Philippines, Malaysia, Indonesia, Taiwan and China where the culture operations were entirely restricted to artisanal sectors. Ong Kah Sin of the Malaysian Department of Fisheries has laid the groundwork for the culture of *Scylla serrata*. As the price of crabs increased, farmers started to supplement their crops by stocking juvenile crabs in traditional ponds where milkfish or penaeid prawns and or seaweeds were cultured (Anil, 1997).

The technology of crab farming practices around the world includes grow-out culture and crab fattening. Grow-out culture refers to farming of undersized crabs for comparatively longer periods, i.e. usually 3-6 months, to produce crabs of marketable sizes whereas fattening refers to holding of market sized crabs for 2-4 weeks time to acquire certain desired biological characteristics (Chong, 1993). The aim of fattening is either to produce female crabs with ripe gonads or to convert post-moult soft crabs into hard shelled ones.

Mud crab farming is practiced in commercial scale in countries like Thailand, Malaysia, Indonesia, Philippines, Singapore and Taiwan mainly by artisanal sector (Suseelan and Anil, 1998). In the East Asian countries, most of the grow-out operations were part of polyculture system in which milkfish, penaeid prawns and seaweeds were also produced (Sivasubramaniam and Angell, 1992). Mud crab is a secondary product in milkfish ponds of Philippines. Pond culture of mud crab (Baliao *et al.*, 1999_a) and pen culture in mangroves of Philippines were described by Baliao *et al.* (1999_b). In Malaysia, pond culture was mainly of subsistence nature and duration of culture was two to six months depending on the seed size. Mud crab monoculture has been practiced in Taiwan and South-east Asian countries for several decades in tidal ponds or pens in low lying coastal areas. Pen culture of mud crabs is practiced in Philippines, Thailand and Indonesia (Chong, 1995). In late 1980s crab culture started in Sarawak. Pen culture of mud crabs was done in mangrove ecosystem in Sarawak, East Malaysia (Say, 1997). In Taiwan, crab culture has a long history. It originated in polyculture and developed into monoculture due to increase in demand. Since 1890s, crab culture was practiced in China.

Crab fattening is the latest technology widely followed in Thailand, Taiwan, Malaysia, Singapore and Indonesia. Cages, pens and small ponds with net impoundments were designed for holding crabs for a short period of 3-6 weeks (Marichamy and Rajapackiam, 1997). In Thailand crab fattening in ponds and pens were very popular (Suseelan and Anil, 1998). In Philippines earlier methods of crab fattening involved placing crabs in holes along the seashore. The holes were covered and food was given often. This practice was pioneered by private sector primarily to meet the demands of domestic and foreign markets. Mud crab fattening in fish ponds in New Washington, Aklan was described by Ladra (1992). Floating net cages were used in Malaysia for crab fattening (Liong, 1992). The culture of mud crabs is only picking up in many countries especially those bordering Bay of Bengal. Even in South-east Asian countries where crab farming is traditionally practiced, the development of this sector is rather slow due to several inherent problems like inadequate supply of stockable crabs (Suseelan and Anil, 1998).

Crab farming in India before 1990 was restricted to experimental culture and growing of crabs trapped in traditional shrimp culture (prawn filtration) ponds (Anil, 1997). Culture experiments were conducted by many workers to study growth, reproduction and survival (Kathirvel, 1980; Natarajan and Thangaraj, 1983; Marichamy *et al.*, 1986; Bensam, 1986).

Mud crab culture has been taken up as an important source of income generation in coastal rural sectors of Kerala, Tamil Nadu and Andhra Pradesh (Suseelan and Anil, 1998). Crab culture and fattening practices followed were described by Ahilan (1999), Anil (1997) and CIBA (1997a). Mud crab farming has been taken up in coastal rural sectors of Tamil Nadu, Andhra Pradesh and Kerala as an important source of income generation for they command good price in the international market (Suseelan and Anil, 1998) and fetch the country good foreign exchange. Unutilised or underutilised water bodies in the country could be used for crab farming (Sathiadhas *et al.*, 1996).

Inadequate supply of seed crabs is the major constraint faced by farmers (Suseelan and Anil, 1998). The indiscriminate and excessive exploitation of crabs from the wild is bound to affect the natural population (Marichamy and Rajapackiam, 2001). Other problems reported were non-availability of cheap commercial feed, high mortality and poor survival rates, wide variations in growth and difficulty in acquiring sufficient trash fish (Kristensen, 1992). The sustainability of trash fish resources was also a source of concern.

2.1.3. Edible oyster culture

The most primitive methods of oyster culture involved little more than scattering cleaned oyster shells called 'cultch' on the bottom in suitable areas, just before setting and letting nature do the rest until the harvest some years later. As early as first century B.C, Romans employed simple methods for setting of oyster seed on piles fixed in coastal waters and reared them to a size when they were collected and consumed (James, 1987). Seventeenth century Japanese culturists refined this method by using rocks, branches and other objects of suitable size that could be easily moved from place to place.

Bottom culture was practiced in U.S, Canada and France. In U.S, and Canada this persisted due to legal obstacles to leasing portions of seabed. The earliest efforts at off-bottom cultures of American oysters were carried out in the middle and late 1930s (Bardach *et al.*, 1972). In 1673, Gorohachi Koroshiya, a Japanese clam culturist made the discovery that oyster spat would settle on upright bamboo stakes anchored in sea bottom. The next logical step was the development of many types of suspended collectors hung from floats (Bardach *et al.*, 1972).

The most sophisticated and productive oyster culture in the world is that practiced in Japan. All oysters grown in Japan are cultured off-bottom, usually suspended from rafts in coastal areas of 3-9 m depth and rack in shallower depths of

2-4 m. The long line method of oyster culture was first introduced to Japan in 1947 and is becoming increasingly popular, particularly in the North. In addition to lower initial expense and maintenance costs, long lines possess the advantage of withstanding winds, waves and currents better than rafts. It made it possible to grow oysters in exposed situations in the open sea where raft culture was not possible.

In France oysters are grown on-bottom because that is the best way to produce regularly shaped shells preferred by the consumers. Another interesting variation in the conventional methods of French oyster culture was the 'claire'method of fattening and growing oysters as final preparation for the market. Table method was also employed for growing oysters (James, 1987).

In South-east Asian countries oysters are considered as staple food rather than luxury. Although off-bottom culture was practiced, techniques used were rather primitive (Bardach *et al.,* 1972). Raft culture helped Korea to increase their oyster production (James, 1987).

In Netherlands, oyster farming was on a sound footing because all natural beds and potential fattening grounds were leased since about 1870s (Iversen, 1976). Oyster farming in Indo-Pacific region has a history of over 350 years starting from the simple operation of placing rocks in shallow waters as spat collectors (Ling, 1970). In China oyster culture began in the Han dynasty about 2000 years ago. The typical culture methods used were bamboo-stick method in the Northern and Eastern part of Fijian and the stone bridge method in Southern part (Brain and Michael, 1982).

In Taiwan, off-bottom culture method is gaining importance and popularity because of increasing pollution in the shore waters and limited littoral areas (Liao *et al.*, 1992). Tray culture was established in parts of Australia, New Zealand, U.S.A. and Europe. In Australia stick culture was also practiced (James, 1987). In recent years plastic mesh bags have become widely popular along Pacific coast of U.S.A and Tasmania. Lantern and pearl nets designed in Japan were used in several areas for growing cultch-less seed. Some of the more sophisticated methods include raceways and artificial ponds. In Hawaii there are a number of commercial systems growing oyster on land-based operation (Stickney, 2000).

Small-scale bottom culture of oysters by transplanting the spat from natural beds to shallower areas of convenience has been in vogue in some places along west coast like Jaytapur, Utsali, Kelwa, Navapur and Ennur (Rai, 1932). Later the fishermen gave up this sort of culture since they were unable to improve their technique (Brain and Michael, 1982).

Hornell (1910) initiated oyster culture on the lines followed in Arcachon, France and established an oyster farm in Pulicat Lake. Unfortunately the culture programme was hammered due to some unknown reasons. In 1975, Central Marine Fisheries Research Institute (CMFRI) took up oyster culture in Tuticorin, Tamil Nadu for the utilisation and augmentation of local resources and to impart the technical know-how of the oyster culture to the interested private entrepreneurs. After experimenting with different methods of oyster culture, rack and tray method for rearing *Crassostrea madrasensis* was developed. During 1978, the Lab-to-Land programme of Indian Council of Agricultural Research (ICAR) was initiated to disseminate the transfer of technology to the fisherfolk. CMFRI adopted fifteen families of the fisher folk at Tuticorin to take up oyster culture.

Experimental culture of Indian edible oyster was carried out in Cochin backwaters (Purushan *et al.,* 1980), in Mulki estuary in Karnataka (Dhulked and Ramamurthy, 1980; Mohan Joseph and Shantha Joseph, 1983), in Goa (Parulekar *et al.*, 1983), in Anthankarai estuary (Rao *et al.*, 1983), Bheemunipatnam backwaters, Andhra Pradesh (Ruben *et al.*, 1983), Ashtamudi lake in Kerala (Velayudhan *et al.*, 1995) which indicated good prospects for oyster farming.

Oyster culture at Ashtamudi lake was initiated as CMFRI's location testing programme in 1993. The edible oyster spat was transplanted from the CMFRI demonstration farm at Dalavapuram to Narakkal and Chettuva estuary. Seven farmers adopted CMFRI technology. Government of Kerala approved implementation of edible oyster farming in four districts with financial assistance of Brackishwater Fish Farmers Development Agency (BFFDA) by way of subsidy (CMFRI, 1997). In 1995-1996, seven farmers at Dalavapuram, one each at Munambam and Padanna adopted CMFRI technique of oyster farming (CMFRI, 1998). Experiments were carried out at Dalavapuram to upgrade the technology of edible oyster farming (CMFRI, 1999) by cementing the individual edible oysters onto split bamboo poles to grow large uniformly sized oysters so as to market it in live condition. Few more local farmers adopted CMFRI technique of edible oyster culture in Dalavapuram area and fifteen farmers adopting CMFRI techniques were given financial assistance by BFFDA (CMFRI, 2000). Oyster farming was introduced to several new areas of Ashtamudi and Kayamkulam lakes of Kerala where more than 100 farms have come up (CMFRI, 2001). The feasibility of integrated farming of oyster and mussel at Pallipuram in Vypeen Island was also demonstrated.

2.1.4. Mussel farming

Mussel culture is believed to have been started in France by a ship wrecked Irish man Mr. Patrick Watten (Korringa, 1976). It was only post 1966 that culture began in South-east Asian countries firstly on an experimental stage and later on commercial lines. The main countries involved in mussel culture are China, Thailand, Singapore and Philippines in Asia, Spain, Italy, Netherlands and France in Europe, New Zealand and Australia.

Sea bottom culture is widely practiced in Holland, Denmark and Germany. *Bouchot system,* which involves placing rows of stakes at various depths for the spat to attach, was followed in France. By 1960 Japanese raft method was used in Spain. This was an almost immediate success that Spain became the world's leading producer of mussels. Raft was also used in Southern France, Yugoslavia and Italy. Italy had traditionally used rack / stake method and had mussel parks called 'Pergolari' (Nayar and Mahadevan, 1980).

In India green and brown mussel culture was first conducted on an experimental scale by CMFRI. In 1973, experimental culture of brown mussel was attempted at Vizhinjam (Kuriakose and Appukuttan, 1996). Later culture of green mussel on suspended substrata in the open sea was done in 1975 at Calicut. Mussel farming was carried out in Dona Paula Bay of Goa (Qasim *et al.*, 1977), off Madras (Rajan, 1980; Rangarajan and Narasimham, 1980), off Calicut (Kuriakose, 1980) and in Vizhinjam bay (Achari and Thangavelu, 1980; Appukuttan *et al.*, 1980).

Though the technology was developed by CMFRI in the middle and late 1970s it was only two decades later that the first commercial culture of green mussel was started in late 1995 at Anthakaranazhi (Alappuzha district) in Kerala by local fishermen on long lines in the sea with CMFRI's technical support. Mussel culture in estuaries and backwaters was demonstrated at Dharmadom (CMFRI, 1997). A progressive farmer in Padanna backwater of Kasargod district harvested 2.5 t from 160 ropes. Five groups of women identified by the local administration adopted mussel farming in Padanna under DWCRA (Development of women and children in rural areas) / IRDP (Integrated Rural Development Programme). Another four groups in Dharmadom estuary adopted mussel farming with financial support from National Bank for Agricultural and Rural Development (NABARD).

Transfer of technology was done in mussel farming to nine groups in Kasargod district (CMFRI, 1998). Open sea mussel farming was initiated at Narakkal as a demonstration programme with the involvement of four fishermen (CMFRI, 1999) and in Kozhikode by five enterprising mussel pickers (CMFRI, 2000). Mussel farming training was given to Self Help Groups (SHGs) of women in Kasargod, Kannur and Calicut. Mussel culture was also initiated in Beeyam kayal estuary at Ponnani. Commercial mussel culture activity along South-west coast of India picked up in a long way since 1997 in different parts of Kerala and Karnataka (Mohamed *et al.*, 1998; Velayudhan *et al.*, 2000; Vipin Kumar *et al.,* 2001; Modayil, 2003).

The bivalve mariculture practices are low-cost, user friendly, environmental friendly techniques, providing opportunity for rural development and employment generation (Modayil, 2003). Women are the main beneficiaries of bivalve farming techniques. Mussel farming faces constraints like poor marketing facilities, unpredictable seed availability, mortality of seed during transportation, reduced growth during certain periods, meat shucking problems etc. (Vipin Kumar *et al.*, 2001). The development of a proper marketing chain inside and outside the state is imperative for the development of bivalve farming (Modayil, 2003).

2.1.5. Fish farming

Farming of finfish in coastal and estuarine areas has a long history of over 400 years in Indonesia, China and the Philippines with milkfish as the major species and mullets coming next (Ling, 1970). By 1400 A.D itself, milkfish and several other brackish water fishes began to be cultured in Indonesia (Ling, 1977). Large-scale brackish water pond culture of fish and shrimp had its origin in South-east Asia (Fast, 1991). Fish culture has long been practiced in Asia right from the time of Weng Wang; the founder of Chou dynasty. Fish culture emerged as a profitable business by 460 B.C in China. Practical culture of marine and brackish water fishes is largely confined to South-east Asia (Bardach *et al.,* 1972).

The traditional system of brackish water aquaculture which existed in India in the *bheris* of West Bengal, *pokkali* fields of Kerala, *Kher* lands of Karnataka and *Ghazani* lands of Goa banked on impounding of tide borne seed of shrimp and fishes and harvesting them after a growth period. The production was low in them and the farmers were resorting to supplementary stocking or feeding in the traditional system. In 1911 James Hornell suggested the development of coastal saline swamps, backwaters, estuaries, deltaic marshes and saltpan marshes for the purpose of cultivating saltwater fish (Krishnan, 1998).

Milkfish culture probably originated in Indonesia where fish farming in salt water ponds dates back to at least 1400. Since 1821 when the Dutch colonial government began to register fish ponds, the area devoted to aquaculture in coastal regions have more than doubled but methods used in milkfish culture have remained rather primitive (Bardach *et al.*, 1972). Milkfish was cultured in tambaks constructed specifically for aquaculture by clearing and excavating mangrove swamps. Milkfish culture was essentially a monoculture system but the nature of tambak ensured that some extraneous organisms would find their way in. In Taiwan milkfish culture was well established by late 17th century and has played an important role in island's food economy ever since. Despite its shorter history and growing season, Taiwanese milkfish culture is much more productive than that of Indonesia and Philippines.

Hawaii has a long history of milkfish culture where the ancient method of allowing incoming tide to stock ponds has been supplemented by selective stocking (Bardach *et al.*, 1972). In Philippines, milkfish and seaweed *Gracilaria sp.* have the highest production and most extensive culture areas (Liao *et al.,* 1992). In Philippines milkfish culture has been practiced for at least 300 years (Wilson, 1991).

Historically milkfish culture has depended solely upon fry caught in the wild for stocking ponds and pens. Since the late 1980s, Taiwan and Philippines were among the milkfish producing nations that have achieved some independence from the need for wild fry by developing hatchery systems. In Taiwan, hatchery activity is often conducted in two separate phases involving culturists who maintain and spawn broodfish and those that rear fry to the size at which they may be stocked. Milkfish grow out is typically conducted in the ponds although an interesting exception occured in a large lake above Manila Bay in the Philippines known as Laguna de Bay (Stickney, 2000). A review of milkfish culture has been made by Tamaru *et al.* (1995).

Milkfish culture was initiated in India in Madras in 1931 and has since become regionally important. A fish farm was set up at Krusadi Island for milkfish culture in 1944. Around the same time salt water fish farms were set up in Narakkal in Kerala for culturing milkfish and mullet. In India earlier attempts to culture brackish water fishes like milkfish, mullets, pearl spot and sea bass were discussed by Krishnan (1998). The feasibility of monoculture of *Chanos* in PE (polyethylene) lined ponds was successfully attempted by Lazarus (1988). Cage and pen culture was experimented by James (1984). Gandhi *et al.* (1988) attempted polyculture of milkfish with mullet at Mandapam.

For centuries, the farming of mullets has been in vogue as a traditional practice in the Mediterranean region, South-east Asia, Taiwan, Japan and Hawaii in the lagoons, creeks, swamps and ponds. Following a global awareness on the potentialities of large-scale production of mullets, especially grey mullets, efforts were directed not only to improve traditional farming practices such as 'valli' culture in Italy but also to introduce intensive culture practices to enhance their production (Gopalakrishnan, 1991).

Romans and Egyptians cultivated mullets for human food centuries ago. This species was farmed successfully only by collecting the young when they first arrived inshore or by attracting them into impoundments on tidal currents and later placing them in large ponds to feed. In China mullet fry are captured at low tide with dip nets and are stocked directly into brackish water ponds that are generally less favoured than milkfish. Mullets and eels are cultured together in same ponds in Japan. In Arcachon, France, famous for its bivalve production, mullets are grown in a system of many ponds with complicated sluice gates (Iversen, 1976).

In Italian 'valli', mullets are the principal crop with gilthead sea bream (*Sparus aurata*) and European sea bass (*Dicentrarchus labrax*). The most sophisticated use of mullet in fish culture has been developed in Israel where *M. cephalus* and to a less extent *Mugil capito* and *Mugil auratus* are used in polyculture. Two types of stocking systems are practiced in Hong Kong, one in which mullets are secondary to the Chinese carps and the other one in which mullet is the primary crop (Bardach *et al.*, 1972). In Hawaii mullet is traditionally cultured in fish ponds formed by lava rock near the sea. A well known method of extensive culture is" kawa culture" practiced in Aichi Perfecture, Japan in which fry are stocked in waterways in very high densities. Mullet is the main species and is sometimes polycultured with common carp (*Cyprinus carpio*), Crucian carp (*Carassius auratus*), sea bass, perches and eels (Stickney, 2000).

The principal mullet culture areas in India are located in West Bengal and Kerala, but East Bengal and Madras (now Tamil Nadu) also produce significant amount of mullets. Mullets are generally cultured with other fishes mainly pearl spot and milkfish in South India and *L. calcarifer* in further North and in Bangladesh (Bardach *et al.*, 1972). The scientific culture of *M. cephalus* in India was reported by Mookerjee *et al.* (1946), Dwivedi and Reddi (1976), Anon (1985), Mathew *et al.* (1988) and Purushan and Hamza (1988). *Liza parsia* is a favourite species cultured in the *bheris* of West Bengal. Attempts on the monoculture of mullets such as *Liza vaigaiensis* and *Valamugil seheli* fed on artificial diets were reported by James *et al.* (1985).

Groupers are extensively cultured in floating and fixed net cages and coastal ponds in many South-east Asian countries. Pond culture is being practiced in Taiwan and net cage system in Singapore, Malaysia, Thailand and Indonesia. In Saudi Arabia, grow out production trial of groupers were carried out in land based as well as off shore culture facilities (Nammalwar *et al.,* 1997). After 1980, Sparidae and Grouper culture gained popularity and economic importance. Most marine species like those from Serranidae family were cultured in Taiwan. In India grouper culture is more common in Bengal region where it is cultured in ponds, canals, *bheries* and paddy fields.

The main marine species cultured in Japan included yellow tail (*Seriola quinqueradiata*) and red sea bream (*Pagrus major*). Although yellow tail was farmed in Japan since the late 1920s, it assumed importance as a culture species since 1960s (Bardach *et al.*, 1972).

Earlier scientific culture of sea bass was from Central Inland Fisheries Research Institute (CIFRI) using tilapia as the forage fish. The sea bass culture in coastal ponds in Tuticorin by James and Marichamy (1987) gave encouraging results. Experimental biculture of sea bass with tilapia was successfully carried out (Purushan, 1990).

Pearl spot (*Etroplus suratensis*) has been introduced to different parts of India by Fisheries Department of Madras Presidency as early as 1916. The fish constituted an important species in the traditional culture system of the country (Alagarswami, 1990). Culture of pearl spot (*E. suratensis*) was attempted on scientific lines under All India Co-ordinated Research Project (AICRP) with brackish water shrimp and fish in Vyttila in Kerala and Ela Douji in Goa (Anon, 1985).

Brackish water farming not only generated income and employment to the rural poor but catered to the nutritional need of the domestic sector. The unutilised open waters, brackish water lakes and lagoons could be utilised for raising brackish water fishes (Krishnan, 1998). Inadequate supply of finfish seed for culture, complete dependence on natural seed are the main constraints with brackish water fish farming.

2.2. Economics of Different Aquaculture Practices

2.2.1. Shrimp farming

The production economics of fresh water prawn (*Macrobrachium rosenbergii)* farming in Hawaii indicated that the farming was profitable at the then existed average annual production of 3,000 lbs/ acre. The rate of return / acre on investment and on operating costs was calculated at different levels of production and farm sizes (Shang and Fujimura, 1977). Socio-economic feasibility studies of *M. rosenbergii* farming at Palau was done by Blommestein *et al.* (1977). The generalised budget simulation model was used to analyze shrimp maturation facility in Texas (Johns *et al.*, 1981). Break-even prices were calculated for 12 month and 7 month production season maturation facility.

Bio-economic modelling with stochastic elements in shrimp culture was done by Griffin *et al.* (1981). The baseline model indicated a mean profit of $ 679/ ha with a 5% chance of loss. Sensitivity tests of profit in the model illustrated the usefulness of the model in directing future research. Costs and revenues of three stocking strategies of *M. rosenbergii* culture in South Carolina were compared (Sandifer *et al.*, 1982). Economic analysis of small-scale shrimp farming in South Carolina indicated a net returns of $ 157.91 / 0.4 ha pond (Liao and Smith, 1983).

A preliminary economic feasibility analysis of a proposed commercial penaeid shrimp culture operation in Texas revealed that only the polyculture of 75% white-leg shrimp (*Penaeus vannamei)* with 25% blue shrimp (*Penaeus stylirostris)* was economically feasible. The break-even production was 1,526 kg / ha and the pay back period was two years (Huang *et al.*, 1984). An investment analysis for semi-intensive farming in Texas indicated that higher rate of returns and faster pay back period were associated with larger total farm size and larger ponds (Hanson *et al.*, 1985).

Economics of extensive, semi-intensive and intensive culture systems in Taiwan were analyzed for grass shrimp (*Penaeus semisulcatus*) culture. Profitability, break-even points and ROI were assessed for the three types of culture systems (Chiang *et al.*, 1986). An economic analysis of coastal shrimp culture in a mixed farming system in Chittagong-Cox's Bazar region, Bangladesh, showed that with traditional methods of shrimp farming there was little possibility of increasing farm income (Ahmed, 1986). The comparative economics of Taiwan style intensive shrimp culture in Taiwan and Hawaii was assessed by Fast *et al.* (1990).

Fifteen simulated farms were used to evaluate the economies of scale and to compare three *P. vannamei* commercial production strategies in Texas. The semi-intensive strategy was found to give the highest IRR (Internal Rate of Returns) at investments less than $ 0.75 million (Lambregts *et al.*, 1993). Intercountry productivity comparisons of black tiger shrimp culture in Asia for extensive, semi-intensive and intensive culture systems indicated that Sri Lanka had a consistently higher productivity for all the three intensities. India had a consistently high level of productivity for its extensive and semi-intensive systems (Leung and Gunaratne, 1996). Comparisons of production costs of Asian intensive, semi-intensive and extensive shrimp farming systems were done by Ling *et al.* (1997).

The trends and economics of hatchery and grow-out phases of shrimp farming in Asia were reviewed (Shang *et al.*, 1998). The costs and returns of intensive, semi-intensive and extensive shrimp farming systems were compared within the producing country and the economic efficiency of each system was compared among the major producing countries. Cost comparisons of Asian shrimp farming technologies using domestic resource cost (DRC) approach were done by Ling *et al.* (1999). DRC approach focussed on the implication of the comparative advantage for resource allocation which is based on the concept of social opportunity costs. It permits comparison of the relative degree of efficiency in producing an identical exportable commodity among different countries. Results showed that nearly all Asian shrimp producing countries had a greater comparative advantage in exporting shrimp to Japan than to US and European Union (EU) markets largely because of the premium shrimp prices received in the Japanese market. Gross margin analysis of shrimp production of two stocking densities at Kaligonj, Bangladesh indicated benefit -cost ratio (BCR) of 2.57 and 2.87 for the two stocking densities (20,000 and 25,000 PL /ha) respectively (Roy *et al.,* 1999). Costs and returns of low discharge and environmental friendly method of intensive shrimp farming was worked out by Baliao (2000).

George (1974) worked out the economics of seasonal and perennial systems of prawn filtration in Kerala. Economics of *pokkali* cultivation and traditional prawn culture in a sixteen ha *pokkali* field at Vypeen in Ernakulam district of Kerala indicated net income / ha for paddy and prawn as Rs. 674.25 and Rs. 651.37 respectively (George, 1978). Case studies on the economics of an improved method of prawn culture in paddy field in Vypeen Island, Kerala was done by Gopalan *et al.* (1978). The improved method of shrimp culture reported profits whereas traditional units ran into losses. Economics of traditional prawn culture farm in the North Kanara district, Karnataka was analysed and the entrepreneur earned a profit of Rs. 7,770 after meeting farm expenditure (Pai *et al.*, 1982). A rate of return of 15.2% 40.5% and 72.5% was indicated for intensive, extensive and prawn filtration culture systems of India respectively (Srivastava *et al.*, 1983).

Economic analysis of prawn culture in perennial fields in Vypeen Island, Kerala was carried out by Nasser and Noble (1992) with due consideration to hitherto unaccounted loss by predation and diseases reducing its price. An economic analysis of perennial prawn culture practice in Vypeen Island was also done. The productivity and profitability of different types of prawn culture practices in

Ernakulam District were assessed (Jayagopal and Sathiadhas, 1993). Marginal farms in Ernakulam area were found more productive than small and large farms. Average production / ha in seasonal and perennial fields were worked out and break-even cost / kg in perennial field was Rs. 243. An input-output relationship was estimated by Cobb-Doughlas production function. The semi-intensive culture of *P.indicus* in saltpan areas of Tuticorin gave an average production of 955.7 kg / ha / crop. The average annual yield of shrimp and fishes from traditional prawn farming system in India was estimated as 1,070 to 1,570 kg /ha / season with 33.3% shrimps (Purushan, 1996).

Expenditure and income from a typical brackish water farm at Kakdwip, West Bengal was given by Rajyalakshmi (1980). Economic analysis of a commercial Research and Development (R & D) project on prawn culture by Tata oil mills Co. Ltd. in 1981 at Pulicat showed that cost of production / kg of shrimp varied from Rs.10-15 considering the variable cost. Net revenue of Rs. 8,000-20,000 /ha /crop was achieved (Felix *et al.*, 1987).

The details of costs and returns for semi-intensive shrimp farming in a two ha water spread area in Tamil Nadu was discussed by Sukumaran *et al.* (1993). The economics of shrimp farming at Thopputhurai, Vedaranyam in Nagai-Quaid-E-Milet district, Tamil Nadu indicated an input-output ratio of 3.72 (Saju *et al.*, 1994). Alagarswami (1995) has reported a net profit of 21.07% from semi- intensive shrimp farming at Nellore. The costs and earnings of shrimp farming in Kerala studied by Panikkar *et al.* (1995) has shown a rate of return of 31% and a net profit of Rs. 14,000/ ha. Budget analysis was adopted to workout the economics of improved extensive shrimp farming system in Vedaranyam, Tamil Nadu. Benefit-cost ratio (BCR) on variable cost and total cost were 2.62 and 2.4 respectively. Overall economics was found to be profitable (Jayaraman *et al.*, 1996).

Economics of shrimp farming in Kakinada area of Andhra Pradesh was discussed by Reddi (1978). High density, short term farming of *P.indicus* in a pokkali field in Vypeen island, Kerala revealed the potentiality of paddy field ecosystem of Kerala to sustain a many fold increase in the production of quality shrimp (Gopalan *et al.*, 1982). An economic analysis of prawn culture in Andhra Pradesh was done where the adoption of prawn culture was found to be highly encouraging (Jayaraman *et al.*, 1987). Economics of prawn culture practices in

Tuticorin area, sources of financial and technical aids available and suitable areas developed for coastal farm were discussed by Marichamy and Rajapackiam (1987).

Socio-economic analysis of prawn farming in Puri and Ganjam districts of Orissa revealed lower average income in Ganjam district. The situation in Puri was better because of higher price level and higher average production (Panikkar, 1990). Comparative cost-profit analysis of five different farms and the relationship between cost of construction / ha and farm size was analysed (Vishwakumar, 1992). Feasibility studies for a twenty ha *P.indicus* farm at Panangad, Ernakulam district, Kerala revealed production cost of Rs. 75.14 for 1 kg of shrimp. BCR was 1.25 and IRR 19.51. Pay back period was five years (Sharly, 1992).

The costs, break-even output and profits of brackish water farming under different systems of operation in Krishna district of Andhra Pradesh were given (Anon, 1993). Economics of brackish water prawn farming in Nellore district of Andhra Pradesh indicated an average yield of 1,161.2 kg /ha/crop. The study revealed that brackish water shrimp farming was highly capital intensive rather than labour intensive and that large farms derived the scale economies (Usha Rani *et al.*, 1993).

Analysis of factor-product relationship in shrimp farming using a production function approach indicated a rate of return of about 31%. Costs of production varied from Rs.12 to Rs. 23 and value realized per kg shrimp was Rs. 25.17 (Kumar and Panikkar, 1993). Feasibility studies for culturing *P.monodon* in a sixty ha farm having necessary facilities like peeling shed indicated a BCR of 1.05 and IRR of 30.15%. The pay back period was 6.87 years (Santhosh, 1993). Feasibility studies for a twenty ha farm for *Penaeus merguiensis* in Gujarat completely depending on seawater indicated a BCR of 6.423 and IRR of 25.51. Production cost / kg shrimp was Rs. 78.73 (Ram Mohan, 1993).

Prospects of farming *P.indicus* in Gujarat was studied by Gopalakrishnan and Thaker (1995). The cost analysis indicated annual net income of Rs.15 lakhs after taking into account depreciation and interest on capital but excluding repayment of capital investment. Annual cost of production for a hatchery of 5 million PL annual capacity was also given.

The break-even analysis of brackish water shrimp farms in Krishna district of Andhra Pradesh doing extensive, improved extensive and semi-intensive farming was done. Different systems of culture operations breaks even at different levels of output for different levels of financial investments. The study identified improved extensive system as the ideal system for sustainable aquaculture (Krishnan *et al.*, 1995). Economics of extensive shrimp farming in Vedaranyam Taluk, Tamil Nadu during white spot disease outbreak was analysed by Sukumaran *et al.* (1995). A lower production of 555 kg/ha /crop was reported resulting in heavy economic loss to the shrimp farmers in the area. Comparative economics of *P.indicus* and *P.monodon* under extensive shrimp culture practices in Tamil Nadu was given by Saju *et al.* (1995). The economics of semi-intensive shrimp farming in Tuticorin was studied by Balan *et al.* (1996). The average production of shrimp was 4.6 t /ha / crop. Profit / kg of shrimp based on total cost and on total variable cost worked out to Rs. 101 and Rs. 129 respectively.

Studies on growth and production of *P.indicus* in a low saline semi-intensive culture system in Panavally village near Cherthala in Alappuzha district of Kerala revealed a production cost of Rs.159 / kg shrimp and an input-output ratio of 1.26 (Prasad, 1999). The feasibility of semi-intensive culture of *P. monodon* in low saline areas of North Sunderbans indicated that these areas could be utilized for scientific culture of *P.monodon* (Saha *et al.*, 1999). Economics of brackish water shrimp farming in the coastal belt of Uttara Kannada district of Karnataka was studied by Naik *et al.* (2000). Though the net returns were higher in scientific farming, heavy risks like contagious diseases and resultant losses prompted majority of the farmers to revert to traditional cultivation.

Cost of 1 kg of homemade prawn feed made by an innovative farmer in Narakkal that was found to give improved prawn yield was Rs. 6.5 as per the local market rate (Gupta, 1994). Economics of a shrimp feed making unit of production capacity of 200 kg/ day indicated an annual profit of Rs. 1.648 lakh (Sridhar and Srinath, 1998). The cost and return analysis of shrimp feed mill of 1 t feed per hour capacity revealed a gross profit of Rs. 124 lakhs with a returns of Rs. 600 lakhs (CIBA, 2000). Economics of a prawn feed making unit of production capacity 200 kg / day indicated an annual profit of Rs. 1.62 lakhs with an initial investment of Rs. 76,500 (Sathiadhas *et al.*, 2000).

The economics of a shrimp hatchery of capacity 10-12 million PL / year was also discussed (Raje and Ranade, 1978). The economics of marine shrimp hatchery to produce 100 million nauplii annually was discussed by Maheswarudu (1997). Net profit worked out to Rs.10.4 lakhs. Feasibility studies for a *P.monodon* hatchery in Ganjam district of Orissa by discounting method revealed an IRR of 25.28 and BCR of 1.11. The hatchery was found to be highly feasible (Rema Bai, 1991). For a *M. rosenbergii* hatchery of capacity of 10 lakh seeds per 45 days at Kollam, total expenditure was found to be Rs. 17.1 lakhs. BCR was 2.005 and IRR 46.7. The hatchery was socio-economically feasible (Shajina, 1992).

The costs and returns of a *P.monodon* hatchery with a production capacity of 100 million nauplii / annum were analysed. Total costs came to Rs. 7.22 lakhs and net profit worked out to Rs. 6.1 lakhs. Income was Rs. 20 lakhs (CIBA, 1995a). A BCR (discounted) of 1.1 and IRR of 44.44% was reported for a backyard hatchery for *P.indicus* of production capacity 3.36 million PL 20 / annum (CIBA, 1995c). The economics of a backyard hatchery with a production capacity of 3 million seeds with an initial investment of Rs. 3.7 lakhs and that of a medium scale hatchery with a production capacity of 15.8 million seeds was given by Pillai *et al.* (1998). Average production cost of 1,000 seeds was Rs. 126 in the former and Rs. 113 in the latter. The IRR of a backyard shrimp hatchery with a production capacity of 3.36 million per annum was given by Laxminarayana (1998). The profitability analysis of a hatchery envisaged to produce 10 million *P.indicus* in the first year, 10 million each of *P.indicus* and *P.monodon* in the second year, 20 million *P.indicus* and 10 million *P.monodon* in the third year revealed a positive contribution from the third year itself (Sobhanakumar, 1998). *P.indicus* hatchery with a production capacity of 1.65 million seed annually with initial investment of Rs. 2.2 lakhs registered a rate of return of 35%. Cost of production of 1,000 seeds worked out to Rs. 79 (Sathiadhas *et al.*, 2000).

2.2.2. Crab culture and fattening

The economic indicators on mud crab culture at three stocking densities proved that ROI and return on equity were highest for monoculture of mud crab at the stocking density 5000/ ha. Partial budgeting showed no incremental benefit from stocking beyond 5000/ ha. Sensitivity analysis showed that even if the value of mud crabs were to be decreased by 28%, the venture was still economic

(Agbayani *et al.*, 1990). Monoculture of *S. serrata* in ponds in Iloilo, Philippines at stocking densities of 5000, 10,000, 15,000 and 20,000 pieces /ha were compared for economic feasibility. High ROI, return to equity and shortest pay back period were obtained from a stocking density of 5000 / ha. Production cost ranged from 35.78 P/ kg at 5000 / ha stocking density to 55.05 P / kg at 20,000 stocking density. Partial budgeting showed that no incremental benefit was accrued from increasing the stocking density to 10,000/ ha. Discounted economic indicators like net present value (NPV), BCR and IRR were also highest at 5000/ ha stocking density (Samonte and Agbayani, 1992).

Comparative costs and returns of different stocking densities of one hectare crab monoculture and crab fattening in ponds in Balasan, Iloilo, Philippines were assessed. Net income from three crab fattening farms in Iloilo averaged 39,074 P/ ha/ year. Average ROI was 24%. Partial budget analysis of crab showed that no incremental benefits was accrued from increasing the stocking density to 10,000/ ha. The discounted economic indicators for 1 ha mud crab monoculture at stocking densities 5000, 10,000, 15,000 and 20,000 showed highest NPV, BCR and IRR for the stocking density 5000/ ha (Kristensen, 1992).

Pen culture of mud crab in the mangrove ecosystem in Sarawak, East Malaysia indicated an average net income / production / cycle of US$ 1,720 (Say, 1997). Commercial evaluation of monosex pond culture of mud crab *Scylla* species at three stocking densities in the Philippines indicated that highest ROI and lowest production cost were obtained from the system stocked at 0.5/m^2 (Trino *et al.*, 1999a). Partial budgeting analysis showed that no net benefit was accrued from stocking beyond 1.5 /m^2. Monosex culture of both male and female crabs gave ROI of more than 100%. Results suggested culture of monosex at 0.5–1.5 no.s/m^2 to be more economically viable and monosex culture of male crabs to be more profitable. Financial feasibility projections of mud crab monoculture, mud crab-milkfish polyculture and mud crab fattening was given by Trino *et al.* (1999b). Costs and returns from mud crab culture was analysed by Baliao *et al.* (1999a). A rate of returns of 49% was observed. Economic viability of four grow-out culture methods for mud crabs in Philippines was assessed by Agbayani (2001). Sensitivity analysis was done to determine the levels of risks caused by a 20% decrease in the market prices and a 30% decrease in farm production.

The net profit from a one ha crab pond in Philippines excluding the initial cost was reported by Kathirvel and Vishwakumar (1993) as Rs. 33,000. Economics of mud crab culture in Tuticorin has been worked out by Marichamy (1995). Economics of crab fattening and composite fish-prawn farming in Ernakulam district, Kerala was discussed by Sathiadhas *et al.* (1996). The approximate costs to be incurred for grow-out culture of mud crab in ponds and fattening in ponds, cages and pens were worked out (CIBA, 1997a). Net profit for pond culture in 0.2 ha worked out to Rs. 37,000. The net profit for mud crab fattening in ponds of 0.025 ha, in cages of $500m^2$ and in pens of $500m^2$ was worked out as Rs. 48,800, Rs. 57,500 and Rs. 74,900 respectively. Studies on economics of crab monoculture, crab polyculture with milk fish and crab fattening done in the mother crab farm at Tuticorin suggested the economic viability of the culture practices (Devaraj *et al.*, 1999b). Economics of crab fattening and composite fish farming in Ernakulam district of Kerala showed a profit of Rs. 2,66,500 for one acre area. Mud crab farming earned a profit of Rs. 1,11,550 (Sathiadhas *et al.*, 2000). Marichamy and Rajapackiam (2001) have worked out the economics of crab monoculture, crab fattening and crab polyculture systems. Sathiadhas and Najmudeen (2004) have estimated the comparative economics of crab culture, crab fattening and crab fattening with composite fish-shrimp farming.

2.2.3. Molluscan farming

The economic analysis of tray culture of Mother of pearl shell, *Pinctada margaritifera* in the Red sea, Sudan showed that off-bottom oyster farming was economically attractive at a price around 1.5 Sudanese pound/ kg of shell at discount rates of 40% or less (Rahma and Newkirk, 1987). Economic analysis of pearl culture in cages suspended from rafts indicated an IRR of 42.71% and BCR of 1.32 (Ghosh and Palanisamy, 1993).

The tentative economic projection for onshore marine pearl culture was given by Rao and Devaraj (1996). Expected economics of onshore marine pearl culture in the urban vicinity of Vishakhapatanam worked out by Devaraj *et al.* (1999b) indicated a profit percentage of 85.2. Onshore pearl culture was less risky and highly lucrative when compared to open sea pearl culture. The economics of marine pearl production was discussed by Chellam *et al.* (1997). Near shore raft culture method was employed in Valinokkam, a coastal bay in Ramanathapuram district, Tamil Nadu and a rate of return of 55.7% was achieved. Pearls valued Rs. 85,633 was obtained.

Economics of a pearl oyster hatchery of annual production capacity of about 5 million spat at Tuticorin was worked out. The actual production cost of a single 3 mm spat amounted to 9 paise. Profit-cost ratio was 0.414 and profit - investment ratio was 0.218 (Dharmaraj *et al.*, 1997).

Financial feasibility studies of high-density oyster culture in salt marsh ponds by string method in Narragansett Bay indicated an IRR ranging from 6.8% to 26.3% for a larger pond. IRR could be increased by producing uniform sized oyster. NPV and IRR indicated that the 9100 ft^2 system was economically attractive (Walker and Gates, 1981). Cost efficiency of stake and rack hanging methods of oyster farming in Philippines was compared. Statistical analysis indicated that the higher production from the rack hanging method was significantly different from the stake method. Results implied that when production was less than 9,044 kg, rack-hanging method was the efficient technology (Giselle *et al.*, 1998). Economics of sixty racks growing oyster in 0.25 ha area in the intertidal region of the Tuticorin Bay was assessed. Ratio of income to investment was 30.1. The break-even price of one kg meat produced was Rs. 25.63 (Nayar *et al.*, 1987). A net profit of Rs. 4,310 was obtained by edible oyster culture by rack and ren method at Dalavapuram in 300 m^2 area during 1995 (Devaraj *et al.*, 1999b).

Series of experiments carried out in Ashtamudi lake in Kerala revealed that oyster culture could be profitably carried out for a period of 7-8 months from November. The economics of edible oyster culture by rack and ren method in 300 m^2 area was assessed (Velayudhan *et al.*, 1998). A net profit of Rs. 8,185 was obtained with gross revenue of Rs. 21,760. Edible oyster farming in an area of 300 m^2 by rack and ren method indicated a net profit of Rs. 4,310 with a revenue Rs. 10, 940 (Sathiadhas *et al.*, 2000).

The IRR on investment in ocean phase of mariculture of giant clam (*Tridacna gigas*) as a function of the period of ocean grow-out was estimated to be 18% (Tisdell *et al.*, 1993). Bio-economic analysis of sea scallop *Placopecten magellanicus* aquaculture production system in Newfoundland, Canada showed that scallop farming was economically feasible. Sensitivity studies indicated farm business viability to be relatively sensitive to changes in sale price but relatively insensitive to changes in capital cost, labour and other operational costs and to mortality (Penneu and Mills, 2000).

Devaraj *et al.* (1999b) reported a net profit of 77.5% in clam culture with a capital investment of Rs. 80,000. The economics of on-bottom blood clam and black clam culture were discussed by Narasimham (1997). Net profit on investment for an on-bottom blood clam culture in one ha area at stocking density of 300/ m^2 was 51%.

Open sea mussel farming yielded a net profit of Rs. 2,20,000 in 0.36 ha area by long line method (Devaraj *et al.*, 1999b). The economics of long line mussel culture at Byndoor, Karnataka indicated a profit percentage of 144 (Mohamed *et al.*, 1998). A production of 400 kg was reported from a 10 m long line. On shore raft cum rope culture experiment of green mussel with *P.monodon* in a shallow seawater pond system in Okhamandal coast in Gujarat was highly encouraging (Subrahmanyam and Gopalakrishnan, 2000). Open sea mussel farming in 0.36 ha area by long line culture method earned a net profit of Rs. 2.2 lakhs. The cost of production of one kg mussel worked out to Rs. 6 (Sathiadhas *et al.*, 2000). The cost estimates of mussel culture in Mulky estuary in Dakshina Kannada district, Karnataka during 1997-98 was done by Sasikumar *et al.* (2000). The profit percentage was 20. Cost and returns of mussel farming in Kasargod district of Kerala by six self help groups was given by Vipin Kumar *et al.* (2001). A comparison of cost and profit on mussel farming by the then existing method and an improved method was given by Kripa *et al.* (2001). By adopting the new method, farm income increased by more than 18%. An average net operating profit of Rs. 12,800 was obtained by mussel farming in North Kerala (Modayil, 2003). Average production per farm of 777 mussel ropes was 25 tonnes.

2.2.4. Finfish farming

Production and culture of one year yellow tail in Japan earned a net return of $1.53 / fish to management. The average cost of production / fish weighing 1.2 kg was $2.47 and the average selling price was $4 for a fish (Brown, 1977). The costs and returns of hybrid bass aquaculture based on experimental production data in South Carolina were evaluated. The preliminary assessment indicated that the commercial culture of hybrid bass was promising in the estuarine waters (Liao, 1985). The economics of private tilapia hatcheries in Laguna and Rizal provinces, Philippines was assessed by Yater and Smith (1985). Cost analysis of large-scale hatchery for the production of *Oreochromis niloticus* fingerlings in Central Luzon, Philippines was done by Broussard and Reyes (1985). The economics of Tilapia cage culture in Bicol fresh water lakes, Philippines was done by Escover and Claveria (1985). The profitability of tilapia cage culture in Laguna province, Philippines indicated it as a profitable venture in San Pablo city (Aragon *et al.*, 1985). Economics of tilapia cage culture in three lakes of Mindanao, Philippines were compared (Oliva, 1985). A survey of grow out tilapia cage farming in Laguna de Bay indicated low financial performance and poor economic viability (Lazaga and Roa, 1985). The economics of tilapia fingerling production and marketing in Philippines was analysed by Escover *et al.* (1987). The relative profitability of different hatchery systems (land based and lake based) was estimated and economies of scale was analysed. There was inverse relationship between the farm size and labour input per unit area in land based hatcheries. Larger lake based hatcheries produced almost twice as many fingerlings/ man-day labour input as did the smaller hatcheries.

The average ROI and pay back period for all the sites of modular pond system for milk fish in Philippines were worked out (Agbayani *et al.*, 1989). A Cobb-Doughlas production function estimated using survey data from sixty six catfish ponds in West-Central Alabama indicated that more intensive use of production inputs would increase yields and profits (Nerrie *et al.*, 1990). The socio-economic feasibility of salt water cage culture of Florida red tilapia (*Oreochromis* sp.) in Haiti, U.S was investigated by Brass *et al.* (1990). Comparison of production costs to potential market prices indicated that the culture was not economically feasible on an artisanal scale and is a high financial risk on a commercial scale. The economic trade offs between specialisation or integration in pond culture production of hybrid stripped bass was analysed. The overall financial feasibility and associated risks of each production configurations were evaluated. The wide fluctuations in the expected returns indicated the significant amount of risk faced by the producer (Gempesaw *et al.*, 1992).

The economics of broodstock replacement for rainbow trout under production conditions of photoperiod control and uncertainty was analysed by stochastic simulation to represent the nature of egg production as broodstock matures (Logan and Johnston, 1992). An economic assessment of the production and release of marine fish fingerlings for sea ranching indicated a ROI of 84% (Ungson *et al.*, 1993). Economics of joint production of sturgeon (*Acipenser transmontanus*) and roe for caviar was assessed by Logan *et al.* (1995). An economic-engineering approach was used to evaluate the economic viability and health regulatory effects on a trout egg production hatchery located in the North-East region of U.S. The results revealed it was better to shut down and correct a serious disease problem in the hatchery than operating it and experiencing a loss of production (Bacon *et al.*, 1996). An economic analysis performed of a proposed commercial scale 20 ha salt water pond culture operation for Florida red tilapia showed that the proposed operation was not economically feasible (Head *et al.*, 1996).

Economic consequences in sea ranching of several marine fish stocks in Japan, Norway and Denmark was evaluated. The NPV approach indicated that the profitability of such activities heavily depended on the cost of juveniles, return rate and the market price of the recaptured fish (Moksness and Stole, 1997). Bio-economic evaluation of different milk fish fry production systems in Taiwan was done by Lee *et al.* (1997). Costs and returns analysis of gulsha (*Mystus cavasius*) with rajpunti (*Puntius gonionotus*) and silver carp (*Hypophthalmichtys molitrix*) was done by Hossain *et al.* (1998). Costs and benefits from culture of rajpunti (*Barbodes gonionotus)* were assessed by Kohinoor *et al.* (1999a). Cost-benefit analysis of red tilapia and Nile tilapia (*Oreochromis niloticus*) under low input culture systems indicated higher benefits from red tilapia culture (Kohinoor *et al.*, 1999b). Costs and returns of modular method of milk fish pond culture was given by Baliao *et al.* (1999c). ROI was 131% and pay back period was 0.76 years.

Stochastic production frontier analysis was conducted in conjunction with a technical inefficiency model to examine the productivity performance and its determinants in carp pond culture in peninsular Malaysia (Linuma *et al.*, 1999). A nonparametric data envelopment analysis technique was applied for multiple outputs to measure economic efficiency and its technical and allocative components for a sample of Chinese polyculture fish farms. The mean technical efficiency was estimated to be 0.74 (Sharma *et al.*, 1999). The profitability analysis of net cage culture of hybrid tilapia insane Julian dam, Tapaz and Capiz was given by Baliao *et al.* (2000).

Average costs and returns per hectare of fish culture under different management categories in Demea, Dhaka was assessed by Quddus *et al.* (2000). Partial budget analysis of Nile tilapia, *Oreochromis niloticus* cultured within an existing agricultural farm in Kuwait showed that additional income from tilapia represented about 30% additional income from alfa-alfa production (Cruz *et al.*, 2000). Profitability analysis of the commercial grow-out of Pacific thread fin (*Polydactylus senfilis*) under different production systems indicated an IRR of 64 % for a system using purchased sea water and 56% for a system pumping its own water (Cordero *et al.*, 2001). Economics of wild grouper (*Epinephelus conoides*) using three feed types in ponds were compared by Tuburan *et al.* (2001). Feeding juveniles with by-catch was found to be more profitable and resulted in an ROI of 155%.

The productivity and resource use efficiency of inland fish breeding farms of Indian major carps in the coastal districts of Andhra Pradesh was studied (Rao and Nagabhushanam, 1985). Input-output ratios for large and small farms were 1.37 and 1.87 respectively. The break even analysis indicated that a minimum of 4.9 lakhs of fish fry seed must be produced with a break-even output of 45.2%. Economics of the polyculture of different species of brackish water fishes in Vyttila fish farm in Kerala was given by Mathew *et al.* (1988). The economics of fish culture and fish cum duck culture in Cauvery delta region of Tamil Nadu was analysed (Ganesan *et al.*, 1991). The introduction of duck cum fish culture as a component in mixed farming yielded more income and generated more employment. A study was carried out to assess the effects of gaps in stocking, feeding and fertilization on fish production in Madurai district, Tamil Nadu. Production function analysis revealed significant effect of stocking rate, total digestible nutrients, phosphorus, nitrogen and labour on fish production (Suresh *et al.*, 1990).

Costs and returns of composite fish culture in Madurai district of Tamil Nadu was assessed by Suresh *et al.* (1992). The average cost of production per kg of fish was Rs. 5.6 in Madurai north taluk and Rs. 4.5 in Melur taluk. Cost and earnings of three ponds where carp culture was done with different managerial practices in Krishna district, Andhra Pradesh was studied by Padmavathi and Anjaneyulu (1992). Economic feasibility of composite fresh water fish culture in Kanyakumari district was assessed. Net returns was only Rs. 2, 614/ ha. Low yield was due to non-adoption of recommended fish culture practices (Suresh *et al.*, 1993). The techno-economic viability of three intensive fresh water aquaculture technologies was discussed by Palanisamy and Ghosh (1993). Intensive tilapia culture indicated the maximum return. The techno-economic norms and comparative assessment of the economics of raising spawn, fry and fingerlings in a circular carp seed hatchery were given by Ghosh and Palanisamy (1993). Estimated costs of and returns from pearl spot seed production in 0.5 ha area were given by CIBA (1995b). Cage culture of *Pangassius sutchi* in North-west Bangladesh using commercially available grow out feed gave a net profit of Tk. 46.25 for each kg of fish produced and a BCR of 1:1.55 (Golder *et al.,* 1996). Returns were Rs. 1.2 lakhs and discounted BCR (30%) was 1.04%. Economics of fresh water production systems was assessed by Ranadhir (1997). Comparative studies on the fish yield in weed-infested and weedless fish ponds in the environs of Lake Kolleru indicated low fish yield in weed-infested ponds (Padmavathi and Prasad, 1997).

An analysis of production factors in carp farming in Andhra Pradesh revealed a strong relationship of fish yield with stocking densities for all the three major carps. Principal component analysis was used to assess the relationships between farm inputs and fish yields (Veerina *et al.*, 1999). Technical efficiency of carp farms in India was analysed by stochastic production function. The results showed significant technical inefficiencies in carp production in India, especially among extensive farmers. The mean technical efficiencies for semi-intensive or intensive and extensive farmers were estimated to be 0.805 and 0.658 respectively (Sharma and Leung, 2000). The economics of carp culture was investigated in Thanjavur district, Tamil Nadu by Jayaraman (2000). Net income per ha was shown as Rs. 12, 834. The input-output ratios indicated high profitability.

2.2.5. Integrated farming

A case study on the economics of integrated farming systems in Nepal was done by Rajbanshi and Shrestha (1980). Economic analysis of simultaneous and rotational farming systems in Philippines indicated encouraging results from rotational farming systems (Dela Cruz, 1985). The benefits of integrated aquaculture-agriculture systems were reviewed with respect to reduction in cost of production, improvement in efficiency of resource utilisation and increase in profit of operation (Shang and Pierce, 1983). A study was attempted to establish the technical input-output relationships in simultaneous rice-fish culture production systems in parts of Luzon, Philippines (Tagarino, 1985). Comparative economics of rice-fish culture and rice monoculture over two consecutive seasons in Ubon province, Northern Thailand was investigated. There was consistent evidence of higher yields from fields stocked with fish (Sollows and Tongpan, 1986).

Canonical correlation analysis was used to study the influence of management factors on the growth and yield in an experimental polyculture system with tilapia and carps (Mikstein *et al.*, 1988). A comprehensive farm level stochastic and dynamic capital budgeting simulation model was used to evaluate the economic benefits of incorporating a small-scale trout enterprise with a grain and broiler farm. The results indicated that combining aquaculture production with traditional agriculture increased expected income and reduced risk substantially (Bacon *et al.*, 1994). An economic analysis of rice-fish and rice monocrop at Gouripur, Mymensingh was done to work out the per hectare input use (Haque *et al.*, 1998). Interspatial productivity differences of extensive farms in Indonesia practicing various forms of polyculture and milkfish monoculture was examined by total factor productivity index (Cordero *et al.*, 1999). The effects of introducing duck into fishponds on water quality, natural productivity and fish production together with the economic evaluation of the integrated and non-integrated systems were studied by Solimon *et al.* (2000).

The effects of various inputs on fish production under composite fish culture in different regions of India were studied by Rout and Tripathi (1988). Comparative economics of four aquaculture species-giant fresh water prawn, hybrid tilapia, milkfish and Asian cat fish (*Clarias batrachus*) under monoculture and polyculture production in Guam, US was analysed by Fitzgerald (1988). Economic evaluation of paddy-prawn integrated farming in Kerala indicated that the net income increased as the holding size increased (Sathiadhas *et al.*, 1989). Performance of both paddy and *P.monodon* was assessed to study the economic viability of paddy cum shrimp culture in coastal saline zone of West Bengal. Paddy grown as mono or mixed culture did not differ in yield significantly. In dual culture, the BCR was higher (6.83) when shrimp was grown with feed. BCR was maximum (36) when shrimp was grown without feed as sole crop (Maiti and Chakraborty, 1994). Economics of fish seed rearing and paddy cultivation on rotation in a seasonal pond of rural Orissa was studied by Radheshyam and Sarkar (1998). The study suggested the economic profitability of the culture practice. Cost-benefit analysis of *P.monodon* and *L. parsia* under different cropping patterns in Kholna, Bangladesh indicated a BCR of 1.63 and 1.73 for single and double crop respectively (Ali *et al.*, 2000). An economic appraisal of fresh water prawn farming in Thanjavur district, Tamil Nadu indicated a rate of return to investment of 45.34% (Senthilaban *et al.*, 2001). Polyculture of brackish water fishes with *P.monodon* and *P. indicus* gave a yield of 98.5 kg shrimp and 1,571.3 kg fish per hectare (Joseph *et al.*, 2001). Economics of polyculture involving shrimp, sea cucumber, pearl oyster and seaweeds in a one ha pond was indicated by Devaraj (2000).

2.3. Externalities

Economists have studied external effects ever since the day of Marshall and Pigou. Along with the development of the field of environmental economics, the theory of externalities has remained of great and growing importance in economic science. According to Mishan (1971) 'the essential feature of an external effect is that the effect produced is not a deliberate creation but an unintended or incidental by-product of some otherwise legitimate activity'. The existence of externalities leads to a deviation from the first best neoclassical world in which price mechanism takes care of an efficient resource allocation i.e. **pareto efficiency**. So it is commonly recognized that externalities are an important form of market failure. It is generally accepted that the source of externalities is typically found in the absence of well-defined property rights.

External effects are defined by Verhoef (1999) as follows: 'An external effect exists when an actor (the receptors) utility (or production) function contains a real variable whose actual value depend on the behaviour of another actor (the supplier) who does not take this effect of his behaviour into account in his decision making process. Externalities occur when the economic activities of one agent / changes generated by it affect another or have an impact elsewhere in ways other than through price mechanism (Corner and Sandler, 1986). Externality is a common denominator used by economists for all those instances where the activities of one economic actor changes the production function of other economic actors, without them being compensated (Wijkstrom, 1995). An external effect or externality occurs when the production or consumption decision of one individual affects the well-being of another in an unintended way and no payment of compensation is made by the producer of the externality to the affected individual (Perman *et al.*, 1996). Both conditions are necessary for an externality to exist (Pearce and Turner, 1990). If compensation is paid to the affected party, then the cost of production / consumption decision has been internalized and nothing is worse off than were before. Alternative terms for externalities include side effects, spill over, external diseconomies or social effects (Davis and Kamien, 1977; Pearce and Turner, 1990).

2.3.1. Classification of externalities

There are different distinctions in externalities. Externalities can be both positive and negative. A positive externality is the one that produces unintended benefits to a third party. For example, the results of research can provide benefit to people / organizations other than those who paid for the research to be conducted. The most familiar form of negative externality is the costs created by pollution. In many industries, the production process involves the generation of a degree of waste products, either as smoke, noise or water pollutants. These pollutants create costs, which are borne by the society as a whole. These may be real (tangible) costs as increased health costs (Lave and Seskin, 1977; Marakovitis and Considine, 1996) or damage to property or intangible costs like the loss of enjoyment of the natural environment or discomfort through increased noise levels. In such cases, the private and the social costs of the activity diverge and the profit maximising decisions of the produce are not socially efficient (Ruff, 1977). These social costs are not taken into account during the production process thus resulting in a level of production that may exceed the socially optimum level.

Undepletable externalities are the one in which the consumption of the externality by one receptor does not affect the consumption by another receptor. An undepletable externality exhibits two types of market failures at the same time: the external effect itself and the public good (or bad) character. When an individual decides to buy an item, his decision, whenever affects price, not only he, but also all other purchasers bear the resulting increase or decrease. This change in price caused by individual decisions is termed a pecuniary externality. Technological externality refers to more or less direct effects, other than price changes, that one decision unit might impose on another. Another specific type of technological externality is congestion externality where each actor is at the same time supplier and receptor of the effect.

The policy implications of externalities are optimisation, compensation, internalisation and regulation of externality. An externality is optimised when its level is consistent with optimum resource allocation according to the potential pareto criterion. An externality is compensated with when a (financial) transaction takes place between the supplier and receptor of the effect, which compensates for the receptor's welfare effects due to externality. Internalisation of an external effect involves the removal of its external character making it 'internal to the economic process'. Regulation can be used for direct government intervention regarding the externality by means of price instruments, command and control measures, tradeable permits or any other means.

2.3.2. Valuation of externalities

There are a variety of approaches to the valuation of non-traded goods and services (intangibles). Some are based on the surrogate market techniques such as the effect of an environmental feature or change on property values or the transport costs incurred in accessing an environmental benefit (GESAMP, 2001). Different methods for the valuation of natural resources were discussed by Kadekodi (2001). Aver-Def expenditure method (Avoidance cost approach method) mainly used for valuing degradation of environmental resources by estimating the cost of avoiding such changes in the environment, productivity method for estimating environmental costs in terms of loss of production arising from depletion of resources like reduction in the area under culture, changes in cropping pattern, reduction in yields were dealt with. Hedonic price method which is based on the assumption that the changes in land / property prices due to a change in the environmental amenity was reflected in the value attached to the amenity. When the market does not exist for environmental resources, CV methods are used. This was computed by asking how much people were willing to give up to have a specified environmental quality improvement happen. This method was also used in terms of how much people were willing to accept as a compensation for an environmental resource. Chandrakanth (2002) discussed different approaches in the valuation of natural resources. Evaluation of non-market goods or goods which are not currently on the market, like the potential benefits of a particular change in policy, is performed by CV method. This is based on the argument that individual's responses to hypothetical markets are comparable to actual markets (Mitchell and Carson, 1989).

CV uses hypothetical situations to place monetary values on goods and services for which no market system exists (Spurgeon, 1992). Contingent valuation methods value the good in its entirety; nothing is revealed about the value of different attributes that comprise the good. This can be undertaken by valuing the good holistically and then asking further questions to value the individual elements of the good. In CV, responses are sought from individuals as to their actions contingent on the occurrence of a particular hypothetical situation (Garrod and Willis, 1999). In CV people's willingness to pay (WTP) or willingness to accept (WTA) is estimated using interview/ questionnaire techniques. The latter may be used in respect of environmental quality and biodiversity issues. These approaches are widely described in the literature (Pearce and Turner, 1990; Kahn, 1998) and in relation to the valuation of ecosystem function was reviewed by Costanza *et al.* (1997).

Where comprehensive CBA is not used, economic analysis can nonetheless be used to shed light on specific issues such as 'costs' of pollution / habitat destruction associated with particular activities. Where actual costs are difficult to estimate, the 'opportunity costs' associated with not developing or polluting resources can be estimated and compared with the possible positive impacts. It can provide information on the nature of the "trade-off" between competing uses of coastal resources, which is vital for economically sound and well-informed decision-making (GESAMP, 2001).

Tolley and Babcock (1986) used CV to evaluate non-market goods such as air quality and health risk. Harrison and Rubinfeld (1978) measured marginal WTP as a percentage of income for an improvement in air quality at designated high levels of nitrogen oxides. Two alternative means of controlling negative externalities (pollution) namely the use of ex ante regulation and the use of ex post liability were compared by Rojas and Segerson (1987). The results were used as background information in analysis of two case studies of ground water pollution. CV survey method was used to measure the economic benefits of best management practices used to reduce agricultural nonpoint source pollution in Tar-Pamlico River in Eastern-north Carolina. Age, number of children, income and expected recreational use were determinants of WTP (Whitehead and Groothuis, 1992).

A dynamic model of ground water pollution from the intensive agrochemical use was developed to capture the possible externalities and analyse the policy options in protecting the ground water resources (Chandra Babu *et al.*, 1992). Respondents were willing to pay FF (French Franc) 215 and FF160 on an average for improved water salubrity and preservation of the ecosystem against eutrophication respectively in Brest natural harbour, France (Le-Goffe, 1995). The mean gini approach was used to analyse stochastic externalities generated by agricultural production. The model addressed the problem of ground water pollution caused by excessive fertilizer application (Shalit, 1995). Respondents were asked about their WTP for three proposed programmes designed to reduce various environmental problems in San Joaquin valley CA. A logit model was used to examine the effects of geographic distances on respondents' WTP for each of the three programmes (Pate and Loomis, 1997).

An economic approach to pollution control in Scottish salmon farming was discussed by Soley *et al.* (1994). Garrod and Whitmarsh (1995) argued that economics could provide an insight into marine pollution causes as well as offer a frame work for designing regulatory instruments. The economic loss of harmful algal blooming in Korea was discussed by Lee and Chah (1996). Externality effects of common property resource degradation due to industrial pollution in Muthupalayam village in Coimbatore was analysed by Sekar (2001). Hedonic and contingent valuation models employed to study the influence of river degradation consequent to industrial effluents on land value, sheep population and crop area showed changes during the last thirty years due to decline in soil and water quality owing to pollution. Aver-Def expenditure worked out to be Rs. 545/ ha.

The externalities and economic valuation of tannery pollution hazards in Vellore were evaluated within a sample frame. Tannery pollution seriously affected sugarcane followed by paddy. The decline in crop production/ ha was monetarily evaluated and farms were graded as seriously affected, moderately affected, low affected and non-affected. Aver-def expenditure was worked out for land, drinking water and irrigation water (Amarnath and Krishnamoorthy, 2001). Environmental costs of industrialization in Gujarat were estimated in terms of loss of property value on account of air pollution by Maya Shah (2003).

Economic analysis of pollution of Panchganga River by domestic waste water from Kolhapur Municipal Corporation revealed that more than 90% of the respondents were willing to pay additional water charges for improved water quality (Deshmukh, 2003). An economic assessment of the environmental damage caused by industrial water pollution in Tiruppur was studied by Appasamy *et al.* (2003). The total irrigated area declined from 16,262 ha to 14,262 ha between 1985-87 and 1997-99. The total annual loss in the fishery sector was estimated to be 1.47 million. The foregone value of local ground water was estimated to be Rs. 98 million/ year. The nature and magnitude of environmental pollution in four small industrial clusters in Karnataka were ascertained and appropriate abatement measures were identified and their costs and benefits were determined (Subrahmanya and Balachandra, 2003). Pollution abatement measures in brick and tile making units have to focus on labour skill levels along with the technology factor. In silk reeling units, a gasifier based system would result in enormous energy cost savings and substantial reduction in pollution levels. The only solution to pollution abatement in puffed rice making is to encourage them to use only rice husk and not scrap tyres and to ban their use through legislation. The use of efficient technologies could reduce pollution and save energy in foundry cluster.

The degree and extent of pollution load in Gujarat industrial development corporation industrial estates were assessed and the economics of common effluent treatments were studied by Jani (2003). The average output per unit was Rs. 232 million, value added was Rs. 74 million and employment generated was 200 labour days. Waste water treatment costs appeared to be 20-22% of total production costs. Considering very high value additions and employment per unit it is prudent to find effective pollution control means rather than closing down polluting units.

Market based instruments were designed and assessed to improve economic and environmental performance of the industries in Jamshedpur region, Jharkhand (Gupta, 2003). Monetisation and demonstration of cost effectiveness of pollution prevention and waste minimisation practices with recourse to corporate green accounting frame work in four industrial units was done by Khanna (2003). Gray and Shadbegian (2004) examined the determinants of environmental regulatory activity and levels of air and water pollution for 409 US pulp and paper mills and the benefits to the surrounding population from pollution abatement. Ihlanfeldt and Taylor (2004) studied the externality effects of small-scale hazardous waste sites on commercial and industrial properties and it was found to negatively affect the market value of nearby commercial and industrial properties.

CV was also used for quantifying consumer's WTP for reduction in food borne risk (Hammit, 1986). Other studies on seafood consumption have used these techniques (Lin *et al.*, 1991; Krishnan *et al.*, 1999).

A simple travel cost model and CV method was used to measure the value of recreational fishing for an anadromous species in Central California (Huppert, 1989). Loomis and Creel (1992) studied the recreational benefits of increased flows in California's San Joaquin and Stanislaus rivers using multinomial logit model and the trip frequency model. A nested run approach was used to estimate the demand for lake recreation in North and South Carolina and recreationists' willingness to pay to visit the lake per trip (Aruna, 1998). WTP of Utah angler sub-groups were analysed under six hypothetical fishing scenarios (Satar, 1999). A travel cost demand model was used for recreational angling in Port Philip bay for angling snapper, *Pagrus auratus.* A final preferred Poisson count model was used to calculate annual angler surplus and total benefits to the angling population (Li, 1999).

The consistency of individuals WTP responses for increases in the quantity of grey whale populations was tested by Loomis and Larson (1994). Split sample design and paired responses for WTP for several endangered fish and wildlife species in the US showed that the benefit for maintaining critical habitat for these species exceeded the costs (Giraud *et al.*, 1999). Bandara and Tisdell (2004) reported from a CV survey among urban residents living in three selected housing schemes in Colombo that the urban residents could compensate the farmers in the areas affected by human-elephant conflict and be better off than in the absence of white elephants in SriLanka.

Evaluations of the WTP for marine resources were not consistent among subgroups of the Norwegian population asked for its WTP for clean fjords. In four studies undertaken to find WTP there was a factor of about three between the highest and lowest estimates (Seip and Hem, 1993). The ecological quality of wetlands in the proposed Donau-Auen National park in Austria was valued by means of a WTP survey (Kosz, 1996). A CV survey was designed to estimate the economic value people would place on controlling marine debris on recreational beaches in New Jersey and North Carolina (Smith *et al.*, 1997). CV method was used to estimate the social benefits of a set of environmental and urban improvements planned for the waterfront of the city of Valencia (Spain) as a consequence of the expansion and restructuring of its trading port. Spike model was applied to the data and to test the validity of it, non-parametric approach was used and the results showed similarities between the two (Saz-Salazar and Garcia-Menedez, 2001).

Various models like travel cost model, hedonic price model, CV model, linear programming model and production function were studied to assess the economic values of water resources (Zheng, 1997). Externalities in groundwater irrigation in hard rock areas of Bangalore and Kolar districts of Karnataka was studied by Chandrakanth and Arun (1997). The conditional probability of drilling additional wells as a response to negative externality was estimated using logistic model and it was found to be as high as 0.87. The WTP for additional wells estimated by Tobit maximum likelihood methods was Rs. 48,370. The farmers coped with the externality by investing on over-ground storage structures, growing low water intensive crops, adopting water saving devices etc. The double bounded dichotomous choice CV was used to find out the benefit of a tap water quality improvement policy in Korea. Sample selection bias detected was corrected by employing a sample selection model (Yoo and Yang, 2001).

The equilibrium effects of stock externalities and ecological interaction were laid out theoretically in the context of a forest air model. The dynamic differences between stock externalities and ecological interaction were numerically simulated (Hagen and Wacker, 2001). Hansen (2002) proposed a regulatory scheme for shiftable externalities, which facilitates the establishment of a market for the externality. Egteren (2002) examined how regulations to curb emissions from coal-fired electricity generating stations affect public utility pricing regulation when regulators act non cooperatively. The controversy surrounding the issue of negative WTP in CV studies was addressed by Bohara *et al.* (2001).

2.3.3. Externalities related to fisheries

Free markets / public regulations and the externalities in fisheries were examined by Flaaten (1986). Factors involved in the implementation of a social management scheme were indicated and a model was presented for fisheries planning. Alternative policies for controlling stochastic externalities considering both the incentives and risk sharing effects of each was analysed by Segerson (1987).

Logit techniques were used to model the experience, preferences and choices of consumers for seafood products in North east US (Nauman *et al.*, 1995). The effects of socio-demographic factors on consumer ratings of product attributes of an experimental big head carp (*Aristichthys nobilis*) product were analysed by Engle and Kouka (1995). Issues like externalities affecting future trade in aquaculture products were discussed (Lem and Shehadeh, 1997).

The effects of different management policies on the economic incentives to discard fish were examined by Pascoe (1997). The concept of an optimal level of discarding, taking into account the externalities created by discarding was discussed. The effect of market power in the presence of dynamic and biological externalities and the role of different externalities in generating inefficiencies were assessed (Datta and Mirman, 1999).

A case study from Bacuit Bay, Palwan, Philippines where logging induced corrosion had killed coral reefs and negatively impacted fisheries and tourism illustrated the failure of market forces to account for the externalities. This implied that management interventions were needed to ensure long-term use and benefits from common property resources (Dixon, 1989). CV method was used to estimate total consumer surplus value (the difference between what a person is willing to pay for a commodity and the amount he actually is required to pay) for coral reef activities on Great Barrier Reef. Hundloe (1990) estimated it as AUS $6 million/ year. Spurgeon (1998) provided a comprehensive overview of the merits and limitations of using an economy based approach to assess and implement initiatives for coastal habitat rehabilitation and creation. Three coral reef studies by Spurgeon

(2001) indicated that restoration costs could vary from around US $10,000 / ha to 5 million / ha.

The economic implications of production externalities associated with ocean ranching were examined by Arnason (1991). Interstate open access externalities associated with Chesapeake Bay stripped bass (*Morone saxatilis*) were looked into and stochastic externalities generated by agricultural production was analysed by mean gini approach. The model addressed the problems of ground water pollution caused by excessive fertilizer application (Buerger and Kahn, 1989). Strategic enhancement and destruction of fisheries and the environment in the presence of international externalities were discussed (Copeland, 1990).

Externalities in marine fisheries were discussed by Vijayakumaran (1998). The bio-economic implications of various policies in different sectors of fisheries were analysed. A framework for rational exploitation of the fishery of Exclusive economic zone (EEZ) with emphasis on the overall development of the coastal poor was evolved. A number of parametric, semi-nonparametric and nonparametric estimation techniques were done by Giraud *et al.* (2001) using data collected from US households regarding federal protection of endangered fish species. A hypothesis test for statistical equality among estimation techniques was performed using a jack knife bootstrapping method.

The net economic value of fishery and forestry in Bio-Bio, Chile was estimated with the environment as a third sector accounting for positive and negative externalities (Araneda *et al.*, 1996). Pena-Torres (1999) explored how the harvesting technology affected internalization of common pool externalities of the firms in fisheries.

2.3.4. Externalities in aquaculture

Several works have been done in international and national levels on the externalities affecting different mariculture practices. Economic effects of oil and gas development on marine aquaculture leases were studied by Caswell (1991). Coliform bacteria and pesticide residues were found to threaten several shallow water sites. The importance of externalities related with the effects of biological interdependency on individual and global performance of shellfish bed management was looked into by Bailly (1991). A review on aquaculture in Ecuador by Saam

(1996) suggested a tax to internalize the externalities caused by loss of mangroves. He proposed that tax should include discounted stock effects of additional habitat and also non-shrimp related environmental benefits. The major problem was with allocation of property rights and the legal system. A bio-economic management study on red swamp crayfish (*Procambarus clarkii*) that caused significant negative externalities like severe crop damage, by borrowing in field was done using Plourde's model (Junqueira *et al.*, 1996). The influence of regional agglomeration externalities in Norwegian salmon farming was analysed by a stochastic frontier production model. The results confirmed the importance of agglomeration externalities for the productivity of salmon farms (Tveteras and Battesse, 2001).

The externalities involved in coastal aquaculture were discussed by various authors. In a critical review of shrimp culture in Philippines, Primavera (1993) discussed the ecological impact of brackish water milkfish and shrimp culture. Newport and Jawahar (1995) examined the environmental, ecological and socio-economic problems arising due to brackish water aquaculture. The impacts of aquaculture on the environment and the external environment on the aquaculture were discussed by Alagarswami (1995). Socio-economic impacts of shrimp culture have been dealt with in detail by Primavera (1997). Environmental implications of aquaculture like mangrove destruction, water quality problems and pollution, salt water intrusion and conversion of agricultural lands were discussed by Mishra and Rath (1999). Socio-economic effects of coastal degradation in Guntur district in Andhra Pradesh including salinisation, conversion of agricultural lands were discussed by Lakshmi and Rajagopalan (2000). The annualised external cost of shrimp production to the society on account of loss of potable water, loss due to salinisation, loss of human health, loss of fishing income, loss of fishing nets, loss of agricultural production and loss of manpower was estimated to be Rs. 5, 55, 968 (Selvam *et al.*, 2000). The impacts of shrimp farming on ground water resources, agricultural land and the environment were discussed by Sakthivel (2001). Various sustainability issues raised against brackish water aquaculture by the environmentalists and social activists were dealt by Rao and Ravichandran (2001).

The negative externalities generated by aquaculture like pollution, habitat degradation, clearing of mangroves, salt water intrusion, obstruction to fisheries and navigation, displacement of fishers or small scale resource users etc were discussed (Anon, 2001). Sreenivasan (2002) throws light on the impact of excessive shrimp seed collection on the marine shrimp resources, impact of the use of fish feeds on the environment and the social impact on food security, conversion of agricultural land, resultant labour displacement and gender injustice, salinisation and impact of chemicals. The environmental impacts of aquaculture farms in Tamil Nadu and Pondicherry were evaluated. Hedonic pricing method was carried out based on land evaluation and cost of decay. CV method was done based on pollution abatement and willingness to pay for pollution abatement (Rajalakshmi, 2003). Shrimp farming practices and its socio-economic consequences in East Godavari district of Andhra Pradesh has been discussed by Kumaran *et al.* (2003).

There are numerous reports from all around the world of mangrove destruction owing to shrimp farming and aquaculture development. Mangrove destruction from Thailand due to shrimp culture was reported by Aksornkae (1988), Arbhabhirama *et al.* (1988) and Menasveta (1997). Similarly mangrove destruction from Philippines was discussed (Primavera, 1989; Primavera, 1997). Alvarez *et al.* (1989) has reported reduction in mangrove areas in Ecuador mainly due to shrimp pond construction. The reduction in mangrove areas has been related with the increase in shrimp farm area during 1981 to 1987 in Vietnam (Trinh, 1993). The clearing of mangroves in Chokoria Sunderbans in Bangladesh for shrimp farming was reported by Choudhury *et al.* (1994). Macintosh (1996) has discussed in detail mangrove destruction for shrimp farming in many South-East Asian countries. A study commissioned by Global Aquaculture Alliance in 1997 about the interactions of shrimp farming and mangroves involving 5000 farms showed that the overall mangrove loss due to shrimp farm development is less than 3% of the total resource loss (Chamberlain, 2002). Sakthivel and Ramamurthy (2003) have reported that only less than 3% of the mangrove area on the whole has been converted for shrimp farming.

There are reports of shrimp farm construction having taken place in mangrove areas and shrimp farming as an important cause of mangrove destruction in India (Holmgren, 1994; James, 1999). A scientific study made along the coast of Andhra Pradesh by Raman and Gopalkrishna (2002) showed no significant mangrove destruction for setting up of shrimp farms.

There are lots of hues and cries worldwide on the large scale conversion of agricultural lands for shrimp farm and the decrease in productivity in the adjacent crop lands due to shrimp farming. Rao (1989) has reported a case in West Godavari district in Andhra Pradesh where the entire agricultural land in a village was converted into fish ponds. Anon (1995) has reported conversion of 50,134,79 ha of agricultural land in Andhra Pradesh into fish ponds. A detailed study conducted by CIBA (1996) in Nellore, Andhra Pradesh revealed that only 270 ha of agricultural land were converted out of a total area of 3,859 ha of creek based shrimp farming. All the sea based farms in the district were constructed on coastal wetlands. A joint study conducted by CIBA and CIFE in Andhra Pradesh and Tamil Nadu revealed that 12.5-15% of the agricultural lands have been converted into shrimp farms (CIFE-CIBA, 1997).

A study conducted in three coastal districts of Nagapatinam, Thanjavur and Pudukottai of Tamil Nadu revealed that wet agricultural land, dry/waste land and river/tank/sea were the major categories converted for shrimp farming. About 1,221 ha of wet agricultural land in Nagapatinam district was indicated as converted into shrimp farming. In reality most of the lands were not used for any agricultural activity either due to intrusion of sea water during floods or due to the non availability of irrigation water (CIBA, 1997b). A case study conducted by CMFRI in Nagapatinam district of Tamil Nadu (Paulraj *et al.*, 1998) revealed that all the 800 ha of shrimp farms developed were located in uncultivated wastelands where no agricultural crop was raised for the last 20 years.

In Krishna district of Andhra Pradesh at the height of shrimp culture boom, the area under shrimp farming increased up to 32, 000 ha when the actual area of paddy cultivation converted was between 2,000 and 5,000 ha. The shrimp culture suffered a set back and consequently the culture area dropped to 20,000ha. The remaining land became unfit for paddy cultivation due to salinisation. In Sirkali and Mayiladuthurai sub-districts of Tamil Nadu over 7,000 acres of fertile paddy fields were taken over by shrimp farmers. The large number of prawn farms resulted in adjacent fertile fields becoming unfit for paddy culture (Lakshmi and Rajagopalan, 2000). The findings of the scientific survey made along the coastal Andhra Pradesh by Raman and Gopalkrishna (2002) showed that only about 15% of the total agricultural land was converted into shrimp farms. Most of these lands were a barren mass of saline soils unfit for any worthwhile agricultural practice. Sreenivasan (2002) has recorded 57,000 ha of agricultural land diverted unlawfully for *bheri* fishery.

NEERI (1995) reported loss of 40% of productivity of croplands situated further downstream of shrimp farms. Most farmers who suffered losses are external to any decision to lease land for shrimp production and will not receive any benefits from shrimp culture. Gadgil *et al.* (1990) has reported a decline in rice yields from a normal average of 3t / ha to 0.5 t/ha in places where farmers tried growing rice after years of shrimp production. Leasing *gazani* lands to shrimp farmers in Karnataka resulted in irreversible land development because of the continued storage of salt water in ponds. When shrimp ponds closed down due to disease infestation they did not have any alternative uses nor can they be restored to their original status. The field observation during the study by Bhatta and Bhat (1998) showed that the crop lands in the immediate vicinity of many shrimp farms have become completely uncultivable due to high levels of salinity. The shrimp contractors will not clear *gazani* in time to enable farmers to prepare the land properly for rice. This inadequate land preparation affects crop yield and also increases soil salinity. Also the annual lease amount that *gazani* farmers received from the shrimp contractors did not account for the long-term productivity loss that the farmers sustained. Nor did the shrimp production account for losses suffered by the traditional fishermen operating in *kodi* who were barred from fishing freely there. *Gazani* land allocation for shrimp production was not done in an efficient manner.

In countries like Taiwan, Philippines and Thailand abstraction of fresh water from underground aquifers for use in intensive shrimp culture has resulted in saltwater intrusion and salinisation of freshwater aquifers (Primavera, 1991). Communities adjacent to shrimp farming in Bangladesh, SriLanka, Indonesia and Philippines experienced salinisation or complete drying up of shallow wells for domestic water supply (Gain, 1995).

Salinity of agricultural land due to lateral seepage of water from the shrimp farm had led to social conflicts in some parts of India. Traditional systems in West Bengal and Kerala do not lead to such problems as they are located in low lying intertidal zone that is generally inundated with saline water during spring tides. Improved extensive and semi intensive culture systems adopted in Tamil Nadu in elevated areas close to agricultural fields attracted such complaints. According to Yadav (1983) most of the coastal areas in India were saline even in 1983 much before the development of scientific brackish water farming practices. Shiva (1995) has reported a case where local women pressurised a shrimp company to supply free water to 600 fisher folk in Nellore district, India. A loss of potable water of 360 m^3 /ha of shrimp pond every year was reported by NEERI (1995). Contaminated water costs Rs.30/ m^3 to clean and process.

The problem of drinking water salinity caused by shrimp farming was experienced by 65.5% of the villages studied in Andhra Pradesh (Patil and Krishnan, 1997). CIBA (1997b) conducted case studies on soil salinisation in Andhra Pradesh and Tamil Nadu to ascertain the level of salinisation in the vicinity of shrimp farms. In Nellore, Andhra Pradesh the electrical conductivity values obtained were found suitable for most of the agricultural crops. The higher salinity found near the farms could not be attributed to shrimp farm alone since saline waters from Buckingham canal flows in between the land and the farm. The soil salinity profile study of farms in three coastal districts of Tamil Nadu found very high salinity levels up to 250 m from shrimp farms in Nagapatinam district while in Thanjavur and South Arcot district, the salinisation was seen up to 100m only. But salinity was not solely due to shrimp farm but the combined effect of both the farm and the creek.

A case study made in South Arcot district on the quality of drinking water near shrimp farms showed that only the bore well situated 500m away from the shrimp farm had potable water (CIBA, 1997b). A similar study done in seawater based farms in Nellore district of Andhra Pradesh found that any salinity effect could be due to the Buckingham canal having saline water flowing through it (CIBA, 1996). The farms were located between the sea and Buckingham canal which existed even before aquaculture activity started in Andhra Pradesh. The study made by Bhatta and Bhat (1998) found high levels of salinity associated with shrimp farming.

A scientific study made along the coastal Andhra Pradesh to study the impact of shrimp farming on the coastal environment by Raman and Gopalkrishna (2002) found ground water having salinity to the tune of 70-80 ppt at some places. It was found that those high salinity ranges had been there since ages and had nothing to do with commercial shrimp farming which was of very recent origin. The authors could not find any instance of shrimp farming causing salinisation of underground fresh water.

A comparison of shrimp farm effluent with wastes from other potential sources of pollution showed that shrimp farm waste water is considerably less polluting than that of industrial and domestic effluents (Macintosh and Phillips, 1992). Although the quality of shrimp farm waste water is far less polluting than some other sources of waste water, water pollution problems may arise because of large volumes discharged particularly when shrimp farming become too concentrated in areas with limited water supplies or poor flushing capacity. It is too common in Asia for many investors to rush into the same area so that one farm's discharge becomes another's intake (New, 1990). The impact of shrimp pond effluents on the environment and the possible remedies were dealt with by Sze (1998). Dissolved nutrients, dissolved organic matter, total suspended solids and biological oxygen demand (BOD) in the effluents of a marine fish farm devoted to intensive culture of gilthead sea bream was analysed to study the environmental implications of intensive marine aquaculture. Results indicated that the water quality of effluents showed very large seasonal variation (Tovar *et al.*, 2000). The impact of shrimp pond effluents on water quality and phytoplankton biomass in a tropical mangrove estuary in North Queensland, Australia was studied by Trott and Alongi (2000).

Pollution from industrialized shrimp culture has been discussed by Sreenivasan (1995). The quality of waste water from different systems of shrimp farming in India was recorded by Joseph *et al.* (1995). Since most of the farms in India are of traditional extensive type, the possibility of shrimp farm wastes degrading water resource is remote (Rao and Ravichandran, 2001). Chamberlain (2002) reported no long term trend towards water quality deterioration as a result of shrimp farming based on a recent survey made by resource authorities and shrimp producers in US, Nicaragua, Honduras, Brazil and Thailand. Over the last ten years progressive farmers have halved the water discharge/ kg of shrimp produced. Effluent loads from shrimp farms have sharply declined in recent years due to dramatic reductions in water exchange rates. The scientific study made along coastal Andhra Pradesh to investigate whether shrimp farming was polluting the nearby environment showed that most of the critical water quality parameters were well within the normal range. The results showed that arguments implicating aquaculture as a polluting enterprise were exaggerated and away from facts (Raman and Gopalkrishna, 2002).

Shrimp culture in India during the late 1980s was totally dependent on the wild seed. Exploitation of the natural seed was its highest in West Bengal, Orissa and Andhra Pradesh (Rao and Ravichandran, 2001). CIBA studies have shown that several billions of fry or larvae of species other than shrimp may be destroyed while collecting shrimp seed. Only 0.3 to 3.6% of the fry collected are of *P.monodon*. In order to collect 1 tiger shrimp fry, 14 other species of shrimp and 21 fish species were wasted (Sreenivasan, 2002). The increased demand for prawn seedlings sought in aquaculture has attracted many people other than traditional fishers to start fishing in Pichavaram mangrove forests in Tamil Nadu. These fishing methods were non traditional and destructive and have changed the biophysical conditions of the mangrove forest (Lakshmi and Rajagopalan, 2000). During 1990s hatcheries were setup and wild seed collection was reduced and later trade on natural seed was banned to avoid destruction of natural resources. Due to excessive collection of shrimp fry for stocking in the ponds, marine shrimp resources have declined. Removal of mother shrimps for hatchery operations also deprived natural population of shrimp in the sea (Newport and Jawahar, 1995; Sreenivasan, 2002).

A case study by Paulraj *et al.* (1998) in Nagapatinam district of Tamil Nadu observed no major change in the fishing effort and in the annual fish landings during 1991-1994 when shrimp culture was at its peak in the district. While average labour requirement for paddy was 180 labour days/ crop/ha, shrimp farming employed 600 labour days/crop/ha. Average annual income from rice cultivation was found to be Rs. 7, 500 while from the shrimp farm it is Rs. 12,000. Similarly a study by CIBA (1997b) in Nellore, Andhra Pradesh has reported 2-15% increase in employment after shrimp farm establishment and 6-22% increase in income. Also there was improvement in infrastructural facilities like road, transport, sanitation and housing due to shrimp farming.

Before shrimp farming came into existence in coastal Andhra Pradesh, local labourers had to go to far off areas for earning their livelihood for a paltry Rs.10-25 /day. But with onset of shrimp farming local people could get jobs near their villages with daily wages of Rs. 75-100/day. Many are benefited in securing regular employment in shrimp farms as feed boys, pump operators, watchmen etc. at a salary range of Rs. 1,200-1,500/ month with free food and accommodation. Local women got employment in nearby processing plants. The shrimp farming has helped the local population in eking out their livelihood with dignity (Raman and Gopalkrishna, 2002).

However there are reports that the economic benefits of shrimp farming did not trickle down to the residents but remained with the farmers, entrepreneurs and traders (Choudhury *et al.,* 1994). Shiva (1995) has reported that a 40 ha shrimp farm in India employed only five labourers while an equivalent rice farm would need fifty. Replacement of traditional rice production by shrimp farming has had a significant impact on the local labour market. Labour intensive rice production require 350 labour days/ha whereas shrimp farm would need only 150 labour days /ha with a net loss of jobs (Bhatta, 1996). In Indonesia a rice crop required an average of 76 workdays /ha while an extensive shrimp farm required forty five (Barraclough and Finger-Stich, 1996).

Employment of local people in shrimp farms are often limited to low paying unskilled jobs while technical and managerial posts are reserved for outsiders (Primavera, 1997). Growing populations, high rates of employment in other economic sectors and the unskilled nature of the labour community aggravated the plight of those who had lost jobs in traditional agriculture (Bhatta and Bhat, 1998). Women employed in sowing, transplantation, deweeding, harvesting, drying etc. of paddy cannot be employed in shrimp farms. This gender injustice was reported by Sreenivasan (2002).

Construction of large farms in the coastal areas may affect the accessibility to coast for other users leading to conflicts among the various users. In India farms of above ten ha are very few in number and most of the small farmers have holdings less than two ha (Rao and Ravichandran, 2001). A study in Andhra Pradesh found that 83% of the shrimp farms were below two ha in extent, 5% between two and five ha and 11% above five ha in extent. Such small and medium shrimp farms do not pose a problem of obstructing accessibility of local fishermen to fishing areas. Large farms more than twenty ha in extent could pose problems in one way or other. But the number of such farms are very small (Raman and Gopalkrishna, 2002). Obstructions to the movement of the fisher folk, damage to fishing nets and fishes due to projection of water intake structures causing socio-economic disruption by industrial shrimp farming should be scientifically evaluated (Sreenivasan, 2002).

In nutshell the benefits generated by coastal aquaculture were employment generation, increased foreign exchange, improved standard of living of the farmers and the local population, rural development, development of ancillary industries and utilisation of waste/ unproductive lands. The negative externalities generated by aquaculture are mangrove destruction, salinisation of agricultural land and drinking water, conversion of agricultural land, depletion of natural resources, decreased productivity of land, pollution and social conflicts.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1. Sampling Area and Sample Size

In Kerala shrimp farming is practiced in the coastal districts of Ernakulam, Alappuzha, Kollam, Thrissur and Kannur. To assess the economics of shrimp farming a farm-to-farm survey was conducted in Ernakulam, Alappuzha and Kollam districts where the culture is widely practiced and is most prevalent. In Ernakulam and Alappuzha districts both modified traditional and extensive system of shrimp farming are practiced. In Kollam district shrimp farming was restricted to extensive culture. The addresses of shrimp farmers were collected from the BFFDAs of respective districts. Every attempt was made to include maximum number of farms under each category. Sample size was limited to those whose full economic details were available and hence was different for different categories. A sample size of forty-four was selected for extensive shrimp farming practice and forty-five for modified traditional. The questionnaire used for the survey is given in appendices 1 and 2. In Ernakulam district the sampling areas selected were Chellanam, Kumbalanghy, Panangad, Kottuvally, Vypeen, Kadamakudy and Ezhikkara. A map showing the survey areas is given in Figure-1. In Kollam district Monroe Island and Pattamthuruthu were selected for sampling. A map showing the survey areas is given in Figure-2. In Alappuzha district, Pallithodu and Ezhupunna were the sampling areas chosen. A map showing the survey areas is given in Figure-3.

Mud crab fattening and culture practices are prevalent in the coastal districts of Ernakulam, Alappuzha and Kollam. The areas covered under the survey were Kumbalanghi, Vypeen Island, Vallarpadom and Kumbalam in Ernakulam district (Figure-1), Dalavapuram in Kollam district (Figure-2) and Ezhupunna in Alappuzha district (Figure-3).

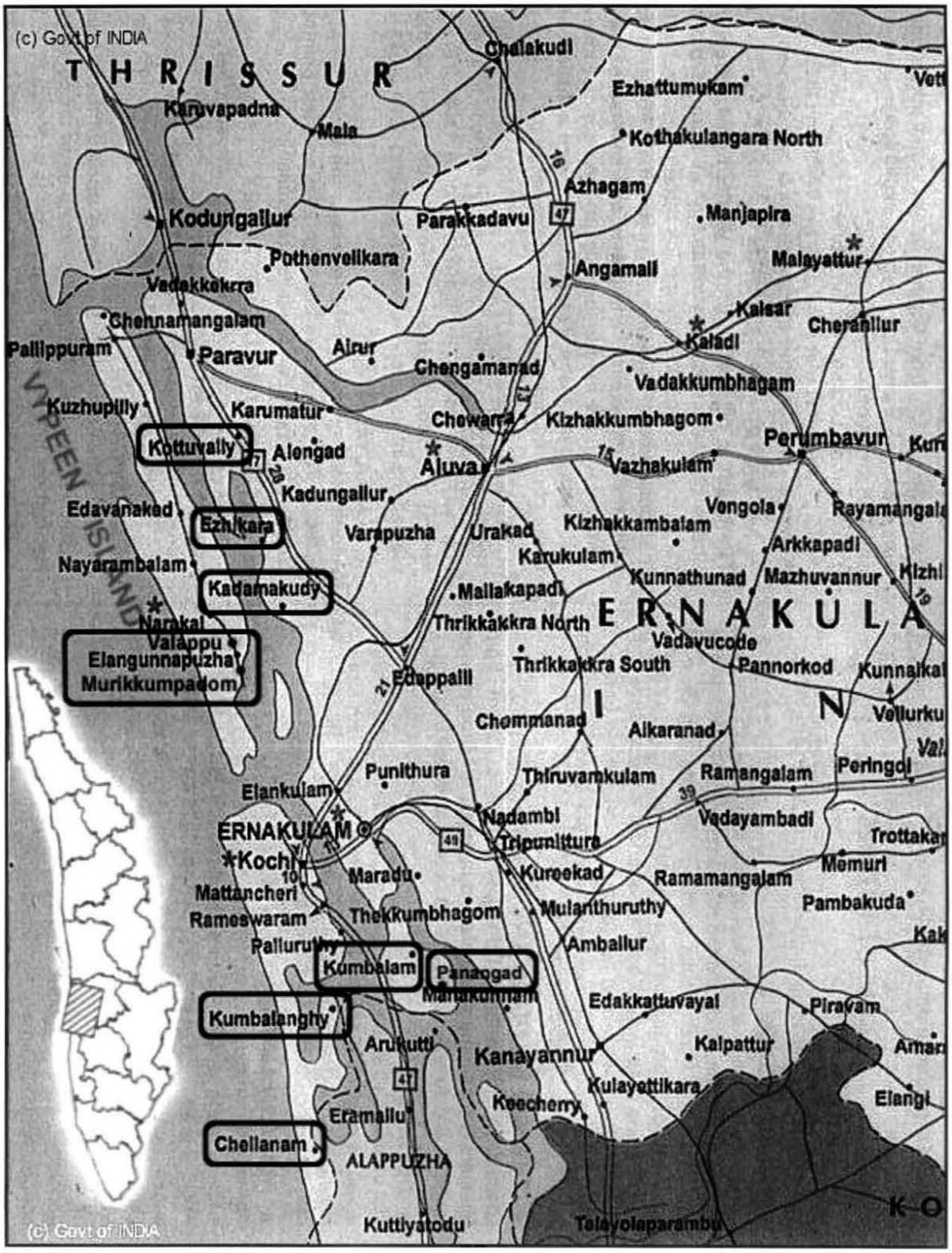


Figure-1.Map showing the sampling stations in Ernakulam district

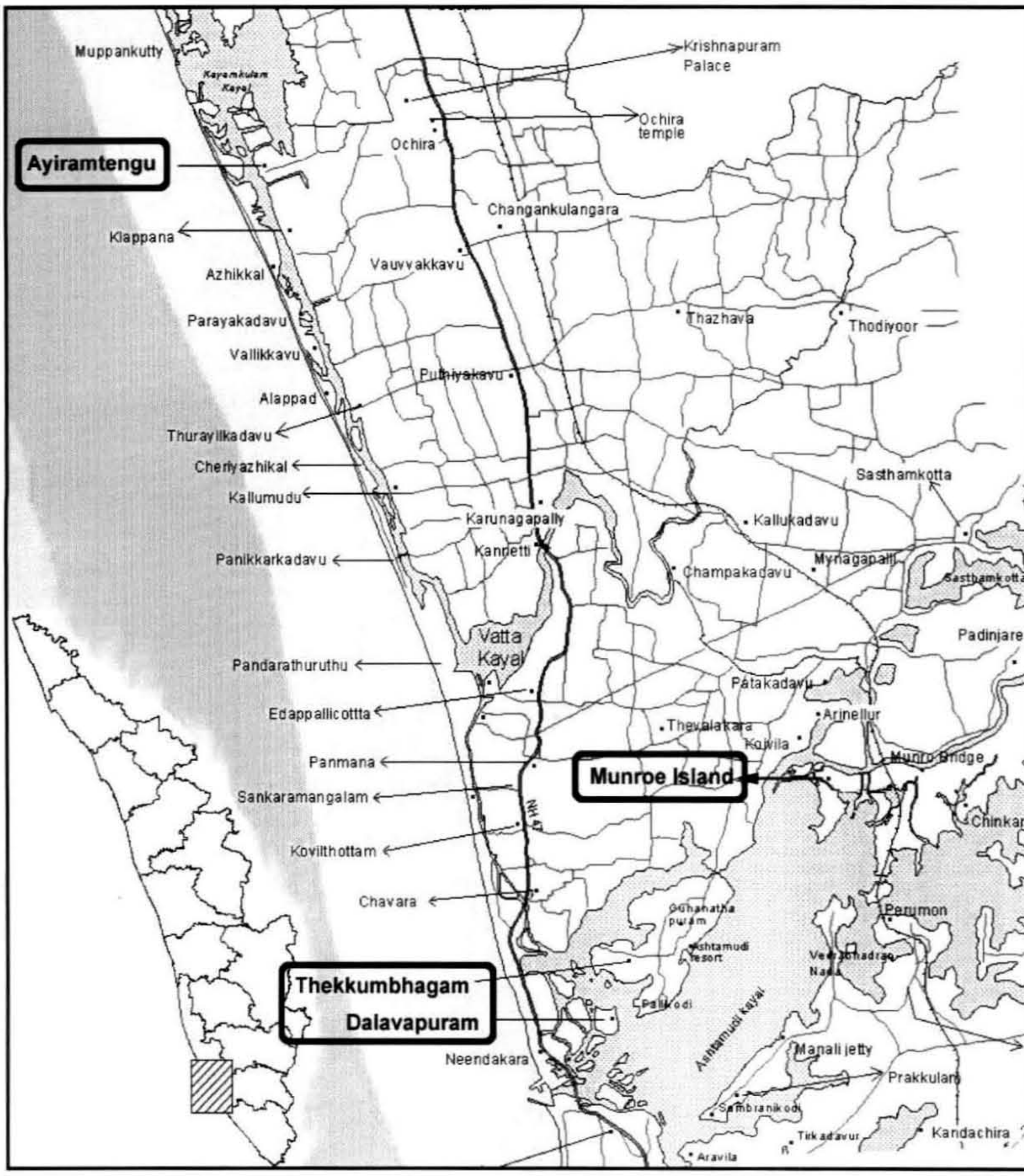


Figure-2. Map showing the sampling stations in Kollam district

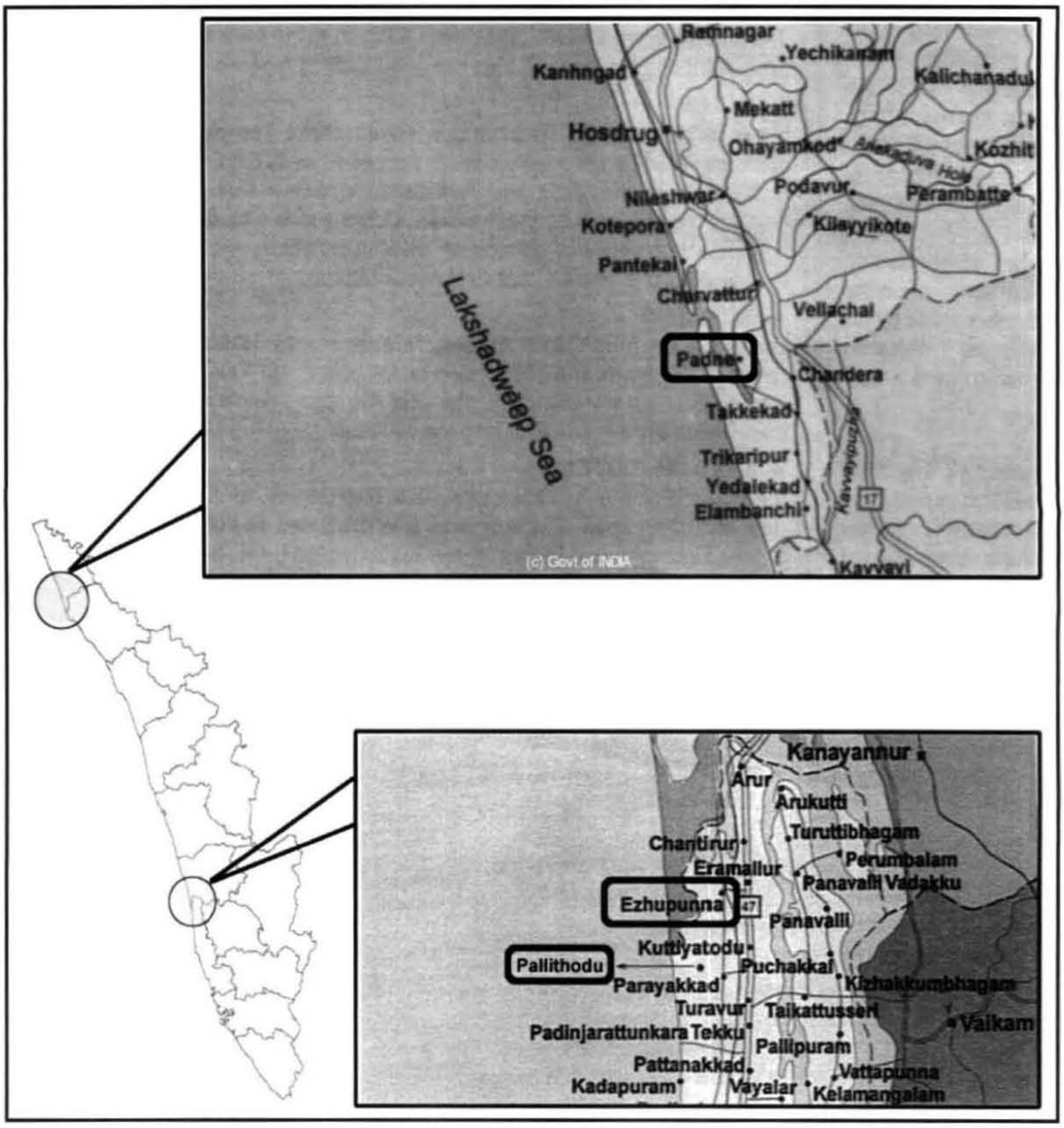


Figure-3. Map showing sampling stations in Alappuzha and Kasargod districts.

Finfish culture is practiced in Elamkunnappuzha, Murikkumpadom and Valappu regions of Vypeen Island. Polyculture of mullets done in three farms, polyculture of fish and shrimp carried out in twelve farms and polyculture of crab, shrimp and fishes in four farms were surveyed. A map showing the survey areas is given in Figure-1.

Edible oyster culture is commercially practiced in Dalavapuram and Thekkumbhagam regions of Ashtamudi Lake in Kollam district and Ayiramthengu region in Kayamkulam Lake belonging to both Kollam and Alappuzha districts. A map showing the survey areas is given in Figure-2.

Mussel culture is done on a commercial scale in Kasargod and Calicut districts in Kerala. The data on economics of the culture practice was collected from Ori and Padanna regions of Kasargod district where the culture is widely practiced by SHGs and individual farmers. A map showing the survey areas is given in Figure-3. A separate questionnaire was used for mussel and oyster culture surveys and is given in the appendix- 3.

A table showing the number of farms selected in the study under different culture practices is given in Table-1. All the farmers were visited three times for the collection of details, one during the beginning of the culture period, one mid way of the culture period and last one after harvest. This helped to obtain correct details on expenditure and returns and also to establish a good rapport with the farmers to reveal the true returns.

For all culture practices except oyster and mussel culture, fixed cost included items like lease amount or opportunity cost of the land, interest at 13% on investment items like pump, sluice gate, shed, canoe and generator excluding land and depreciation on investment items excluding land. Depreciation was calculated using straight line method by dividing cost of the item by its lifespan. For oyster and mussel culture, opportunity cost/ lease amount was not taken into account. The only investment item was bamboo. Variable cost included expenditure on items like labour, feed, seed, fuel, chemicals, transportation, fertilizers, harvesting nets, rings etc. For oyster and mussel culture, additional expenditure under variable cost was incurred on items like coir, rope, net waste, bandage cloth, needle, thread, oyster shell (cultch material) and rent for canoe.

Table-1. The sampling pattern followed for different culture practices

Sl.No.	Type of culture	Area of observation	No. of sample farms
1	Improved traditional shrimp culture	Ernakulam and Alappuzha districts	45
2	Extensive shrimp culture	Ernakulam, Kollam and Alappuzha districts	44
3	Mud crab fattening and culture	Ernakulam, Alappuzha and Kollam districts	24
4	Edible oyster culture	Kollam and Alappuzha districts	22
5	Mussel culture	Kasargod district	30
6	Milkfish culture	Ernakulam district	3
7	Polyculture systems	Ernakulam district	19
	Total		**187**

3.2. Key Economic Indicators

The economic indicators like productivity of land, labour, feed and capital; cost of inputs per kilogram of output i.e. labour, feed, seed and land; operating cost per ha, labour cost per ha, feed cost per ha and seed cost per ha; net profit, net operating profit and break-even production, input-output ratio were worked out for different culture practices(Shang, 1990).

Productivity of Land =Total production (kg)/ Total production area (ha)

Productivity of labour =Total production (kg)/ Total labour input (labour-days)

Productivity of capital =Total production (kg) / Total operating cost (Rs.)

Productivity of feed	=Total production (kg) / Total feed input (kg)
Labour cost per unit of output	=Total labour cost incurred / Total amount of produce (kg)
Feed cost per unit of output	=Total feed cost incurred / Total amount of produce (kg)
Seed cost per unit of output	=Total seed cost incurred /Total amount of produce (kg)
Land cost per unit of output	=Opportunity cost of land incurred /Total amount of produce (kg)
Operating cost per ha	=Total operating cost incurred / Total land area (ha)
Labour cost per ha	=Total labour cost incurred / Total land area (ha)
Feed cost per ha	=Total feed cost incurred / Total land area (ha)
Seed cost per ha	=Total seed cost incurred / Total land area (ha)
Net profit	=Gross revenue - total operating cost of production (fixed cost + variable cost)
Net operating profit	=Gross revenue- total variable cost
Break even production	=Total costs per ha/ Unit Price of produce
Input output ratio	=Gross revenue/ total costs

3.3. Valuation of Externalities

The externalities generated by coastal aquaculture like mangrove destruction, salinisation of water, conversion of agricultural land, pollution associated with different culture practices and the externalities affecting coastal aquaculture practices were identified (Appendix-II).

Pollution was found to affect culture practices in many of the regions surveyed. Ezhupunna, in Alappuzha district, an area severely affected by pollution by the effluents from peeling sheds and processing plants was selected. Monthly analysis of water samples from the farm inlets was done for the parameters like BOD, COD (Chemical Oxygen Demand), ammonia and p^H for three months from May to July, 2003 when pollution was the maximum, using standard procedures. During the summer months pollution was high due to less dilution and during the monsoon months due to relatively high effluent release from peeling sheds and processing plants. Water sampling was done monthly for the three months from the inlets of six farms each receiving water from each of the five canals. Care was taken to collect water during the same time of the day to avoid diurnal variations. A map showing the water canals, processing plants, peeling sheds in the Ezhupunna-Kodamthuruthu area is given in figure-4.

The intake water quality parameters were analysed and the farms were classified into less polluted, moderately polluted and highly polluted based on the values suggested by Anon (1997) with suitable modifications (Table-2).

Table-2. The classification of farms based on water quality parameters

Category	**BOD (mg/l)**	**COD (mg/l)**	**Total Ammonia (mg/l)**
Less polluted	15.00-20.00	70.00-100.00	0.100-0.500
Moderately polluted	20.01-25.00	100.01-250.00	0.501-1.000
Highly polluted	Above 25	Above 250	Above 1.0

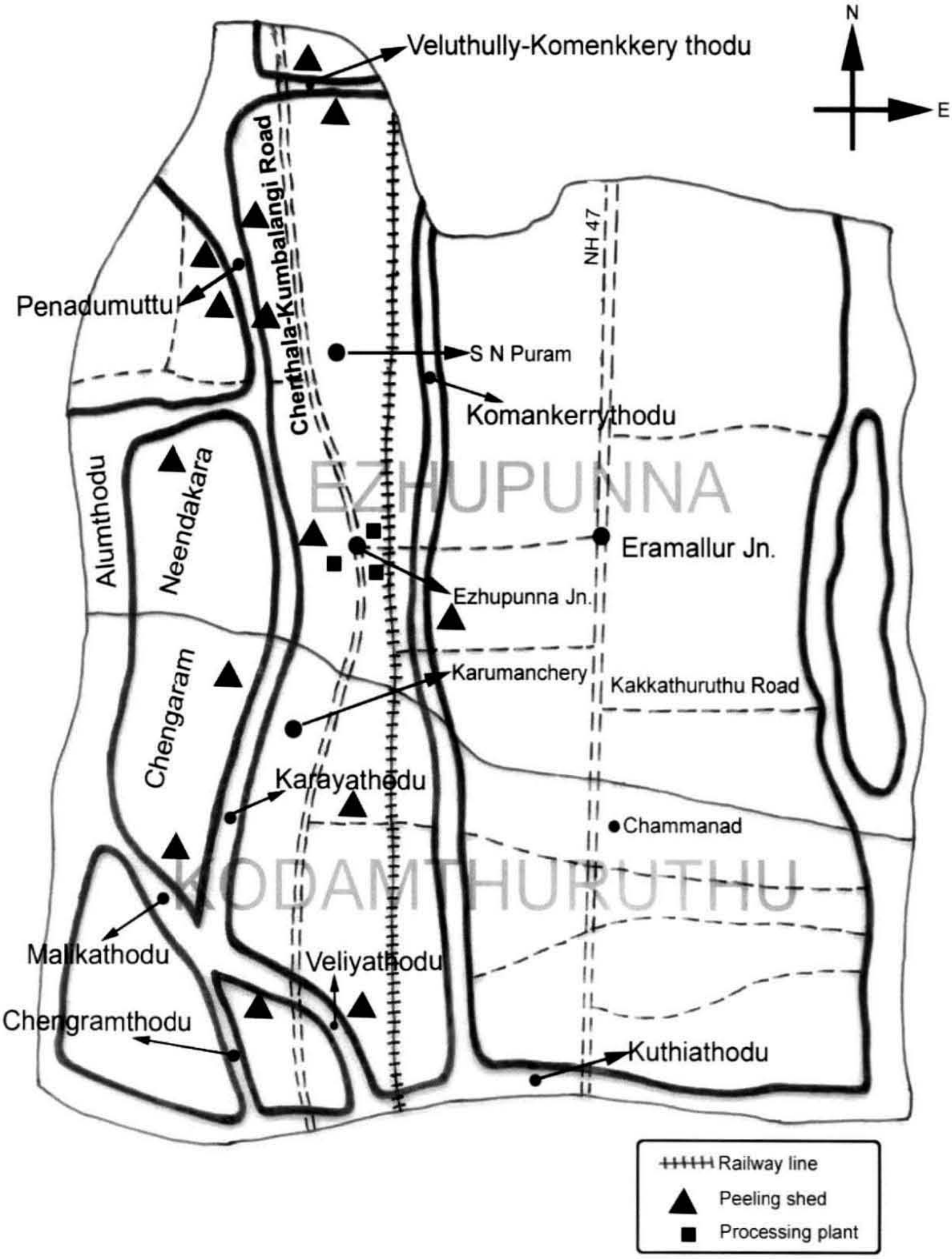


Figure-4. Map showing the water canals, processing plants and peeling sheds in Ezhupunna area.

Hedonic pricing method, Contingent valuation method, Aver-def expenditure method, productivity method and percentage analysis were carried out to analyse the externality 'pollution'.

3.3.1. Hedonic pricing method

Hedonic pricing method was chosen to study the influence of water pollution and its effect on various characteristics of the aquaculture land in deciding its final value. The model used was of the following form.

Log V = $a+b_1WEI+b_2PTB+b_3PI+b_4WQI+b_5CAN$

V = Value of aquaculture land (Rs./ acre)

WEI = Water exchange index*

PTB = Proximity to bar mouth (km)

PI = Pollution index*

WQI = Water quality index*

CAN = Canal from where water is taken into the farm**

The indices were graded and scored as follows

*Low = 1, moderate = 2, high = 3

The grading of a farm for WQI and PI was done based on water quality analysis carried out in sample farms receiving water from the same canal. Since the farms were not showing consistent results in all the three months, farmers' opinion was also taken for grading them.

For grading WEI, the water flow in the canal, depth and width of the canal supplying water to the farm were observed visually. The farmers' opinion on these aspects was also taken into consideration for grading WEI considering their practical knowledge.

**The scoring given for different canals are as follows

Alumthodu = 1, Karayathodu = 2, Veliyathodu = 3, Penadumuttu = 4, Veluthully-Komenkkery thodu = 5.

Log-linear regression was run for assessing the influence of each factor in deciding the land value.

3.3.2. Contingent valuation technique

Contingent valuation method (CVM) was also used to study pollution as an externality wherein the respondents were asked their willingness to pay (WTP) for good quality water, free from pollutants, for aquaculture. The source of pollution, its nature and extent, possible solutions were discussed in detail with the farmers and the peeling shed owners who were the potential polluters and the best possible solution was identified. A treatment plant where water is pooled from all the peeling sheds and processing plants with a capital expenditure of 4 crores was envisaged. Capital expenditure will be met from the Thrithala panchayat and working expenditure from the farmers with governmental assistance. The amount will be collected from the farmers as aquaculture tax. Since the farmers did not have any prior experience in purchasing the environmental good, the range of willingness to pay amount was established by conducting a pre-survey among 194 farmers in the area through an open-ended elicitation method (Appendix-IV). About 48 % were willing to pay to prevent pollution. About 32% of the respondents were of the opinion that polluters have to pay and 20% did not respond for various reasons cited below,

a) Since there were many points of entry for pollutants the idea of treating the water was not practically possible.

b) Government has to undertake such a huge investment like treatment plant and its maintenance which is beyond the capacity of ordinary farmers.

The WTP amount quoted by the farmers for the environmental good ranged from Rs. 100 to Rs. 5, 000 per acre per annum. About 90 % of the farmers who were willing to pay, quoted WTP bids in the range of Rs.100-1, 200. So in the final round of survey an iterative bidding format was used beginning with Rs.100, with the iteration exceeding the previous bid by Rs.100, till Rs.1, 200 (Appendix-V). Ninety-three farmers were included in the final round of survey. To avoid illegitimate responses, the reason for quoting the WTP value was also analysed. The following model was used to find out the influence of different factors on WTP.

$$\text{Log WTP} = a + \text{Log } b_1 \text{ ARE} + b_2 \text{ INC} + b_3 \text{ PER} + b_4 \text{ CUL} + b_5 \text{ SC} + b_6 \text{ PI}$$

WTP	=	Willingness to pay (Rs. / acre/ year)
ARE	=	Area in acres
INC	=	Income*
PER	=	Level of perception on pollution*
CUL	=	Culture practice adopted**
SC	=	Species cultured***
PI	=	Pollution index*

The indices are graded and scored as follows

* Low = 1, medium = 2, high = 3

** Modified traditional = 1, extensive = 2

***_Penaeus indicus_ = 1, _Penaeus monodon_ = 2, others = 3, _Penaeus indicus_ and _Penaeus monodon_ = 4

Log-linear analysis was done to analyse the influence of each factor on WTP. A percentage analysis was done to find out the number of farmers WTP more than Rs.1, 000, those between Rs.500 and Rs.1, 000 and those between Rs.100 and Rs.500.

Aver-def expenditure per acre was calculated for each farm and an average value was worked out. Aver-def expenditure includes the amount spent on chemicals, additional seed and labour because of pollution.

Productivity method was also done to analyse the pollution externality by comparing the productivity of farms affected by pollution and those not affected by pollution provided other factors remain the same. Data on farming areas abandoned, shifting of occupation and species cultured, owners giving away their land for lease, reduction in land value and lease amount, health problems on contact with polluted water were also collected and analysed.

RESULTS

4. RESULTS

4.1. Economic Analysis of the Externalities in Aquaculture - Pollution

4.1.1. Water analysis results

Based on water analysis carried out in thirty farms each in the months of May, June and July, 2003, the categorisation of farms were done and the results obtained are given in Table-3.

The results indicate that 90% of the farms were receiving moderately to highly polluted waters in the month of June and 80% of the farms in July and 70% of the farms in May. This was in accordance with the complaints of farmers and local residents on the increased effluent discharge from peeling sheds and seafood processing plants during the monsoon season (June-July). In the month of May, due to less water flow and dilution, the number of polluted farms was reasonably high. Even with heavy water dilution in monsoon, the number of farms in the polluted category was more than in summer month of May. This was due to the increased discharge of effluents in monsoon season from peeling sheds and seafood processing plants on the assumption that they will get diluted.

Table-3. Classification of farms in different categories (May to July, 2003)

Category	May	June	July
Less polluted	9	3	6
Moderately polluted	12	9	10
Highly polluted	9	18	14

4.1.2. Hedonic model

The results of log linear regression for determining the nature and influence of variables used in the hedonic model are given in Table-4. All variables used in the model except PTB were significant at 1% level. The variables WQI and WEI were positively significant implying the effect of quantitative and qualitative parameters of water on farmland value. PI was negatively significant showing the negative impact of pollution on land value. This was further confirmed by the decrease in lease amount over the years. The variable CAN was significant at 1% level, implying that the land value depends very much on the canal from which water is drawn for aquaculture. PTB was positive but not significant in determining land value. Rather than the distance of the farm from the bar mouth, it is seen that the land value is influenced by the quantitative and qualitative characteristics of water. The analysis revealed that 60.2% of the variation in land value was taken care of by the explanatory variables included in the hedonic model.

Table-4. Variables in the log linear regression analysis of the hedonic model

VARIABLES	STANDARD COEFFICIENT
Constant	0.000*
WEI	0.482*
PTB	0.100
PI	-0.219*
WQI	0.179*
CAN	-0.275*

*Significant at 1% level

4.1.3. Contingent valuation technique

The results of the log linear model used to analyse the influence of each variable on the WTP is given in Table-5. All the variables used in WTP model except CUL were significant at 1% level. The analysis revealed that 54.1% of the variation in WTP was taken care of by the explanatory variables used in the model. The variable ARE was positively significant showing that WTP value increased with increase in the farm area. The variable INC was negatively significant showing that the farmers earning low income due to pollution were willing to pay more to improve their yield and income. The variable PER was positively significant in determining WTP. The farmers who were more aware of the pollution problems were willing to pay more towards prevention of pollution. The variable PI was positively significant showing that WTP increased with increased pollution load. The variable SC was negative and was significant in determining WTP value.

Table-5. Variables of log linear analysis of contingent valuation technique

VARIABLES	STANDARD COEFFICIENT
Constant	0.000
ARE	0.742*
INC	-1.268*
PER	0.889*
CUL	0.279
SC	-0.912*
PI	0.372*

*Significant at 1% level

4.1.4. Percentage analysis

The average willingness to pay value worked out to be Rs. 673. Of the 93 farmers included in the final survey, 67% were willing to pay in the range of Rs. 100-500, 26% in the range of Rs. 500-1,000 and 7% above Rs. 1,000 per annum per acre. The farmers who wished to entrust this amount with any government agency was 80% whereas the other 20% favoured farmers union to collect the amount.

All the farmers cited peeling shed effluents as the primary cause of pollution. In addition to peeling shed wastes, 87% complained of wastes discharged by processing plants, 6.5% of slaughterhouse wastes and 3% of sewage discharges attributing to water pollution.

4.1.5. Aver-def expenditure

The averting or the defensive expenditures are the ones which are incurred to compensate the yield loss due to pollution, like the additional amount spent on neem oil cake, bleaching powder, potassium permanganate, labour, loss of production from the area set apart for water treatment etc. There was one farmer who set apart 1.5 acre of his farm as reservoir out of a total of 7 acre, where he treated water with lime and allowed it to settle down. The water from this farm was taken for aquaculture after it got clear. Some of the farmers applied 30 to 50 kg of neem oil cake per acre twice a month. Bleaching powder was applied in some farms at the rate of 35-50kg/ acre, twice a month. Potassium per manganate was used in some farms at the rate of 100 g / acre. All these chemicals were applied with the intention of reducing the pollution load. The aver-def expenditure per acre per year for the farms ranged from Rs. 110 to Rs. 1,714. The average aver-def expenditure per acre per year worked out to Rs. 618.

4.1.6. Productivity method

The improved perennial farms which are less affected by pollution showed an average production of 951.35 kg/ha/year whereas farms which received polluted water showed an average production of 597.38 kg/ha/year. A comparison done on the economic aspects of improved traditional perennial farms less affected by pollution and those affected by pollution is given in Table-6.

Table-6. Comparative economics of pollution affected shrimp (perennial-improved traditional method) farms (2002-03)

Items	Less pollution affected		Pollution affected	
	Total	Per ha	Total	Per ha
Area (ha)	40.24	1	78.74	1
Number of farms	3	-	18	-
Total costs /year (Rs)	23,72,671	58, 963	52,90,856	67, 194
Total fixed cost / year (Rs)	9,49,302	23, 591	30,52,356	38, 765
Total variable costs/ year(Rs)	14,23,369	35, 372	22,38,500	28, 429
Production / year (kg)	38, 268	951	47,008	597
Gross returns / year (Rs)	34,44,946	85, 610	58,36,524	74, 124
Net profit /year (Rs)	10,72,275	26, 646	5,45,668	6, 930
Net operating profit/ year (Rs)	20,21,577	50, 238	35,98,024	45, 695

The farms coming under moderately to highly polluted category as per the water quality analysis in all the three months were categorised as pollution affected farms and others were put into the less pollution affected category. The input output ratio was 1.45 for farms less affected by pollution and 1.10 for pollution affected farms.

The farmers abandoned culture practice temporarily (16%) especially during peak summer and early monsoon months when water pollution reached its maximum. About 13% of the farmers reported a shift in the species cultured from

Penaeus monodon to *Penaeus indicus*, which required less investment. About 48% of the farmers surveyed reported that the trend of owners giving away their land on lease is on the increase. This was to avoid the possible risk of crop failure due to water pollution and disease onset. The lease amount for shrimp ponds ranged from Rs 8,000 to 30,000 per acre in1995. In 2003, it dropped to the tune of 5,000 to 20,000 per acre. The land value also showed a declining trend. The land value ranged from Rs. 0.5 to 4 lakh per acre in 1995 and in 2003 it declined to 0.5 to 2 lakh per acre. About 9.6% of the farmers shifted farming from the study area to other regions owing to poor water quality and 55% of the farmers reported allergies related to skin on contact with the water.

4.2. Economic Analysis of Externalities Generated by Coastal Aquaculture

4.2.1. Mangrove destruction

Mangrove destruction has taken place in many parts of Kerala for various purposes, shrimp farming being one of the purposes. The farmers were asked during the survey whether their farms were constructed by destroying mangroves and 21.50% of the farmers (of a total of 135 farmers) surveyed indeed remembered that they have destroyed mangroves for aquaculture purpose.

4.2.2. Conversion of agricultural land

In the traditional prawn filtration system that existed in Kerala, the saline resistant variety of paddy *pokkali* was grown during South-west monsoon period and ponds were utilised for prawn filtration in the post monsoon period. To improve the productivity of the traditional system, supplementary stocking and feeding were resorted to. Due to the high profits realised from shrimp farming and low returns from paddy cultivation, some farmers who had sufficient salinity in their ponds during monsoon, went for shrimp culture even during monsoon period forgoing paddy cultivation. As per the land use policy of Government of Kerala, seasonal fields cannot be converted permanently for shrimp farming. Paddy cultivation has to be carried out in these fields during monsoon.

In Panangad region of Ernakulam district, the labour union has made it mandatory for the farmers to grow paddy during monsoon if they have to go for prawn filtration or farming in the post monsoon months. In places like Kaitharam and Kottuvally the labour union has prevented the farmers from using pumps for water exchange for shrimp farming. Also they have prevented the farmers from resorting to any eradication methods for the damage it can cause to the environment.

Many farmers in Chellanam and Kannamaly regions of Ernakulam district are growing shrimp even in the monsoon season without going for rice cultivation exclusively due to profit motive. As a result there have been several incidents of conflicts in the region where outside people come in large numbers and forcefully harvest the produce of the farmers. Many farmers in Nayarambalam, Kadamakkudy, Kottuvally and Kaitharam regions still continue to grow paddy for the simple reason that they do not want to break the conventional practice of growing rice during monsoon.

4.2.3. Salinisation of land and water

In Kerala salinisation of soil and water owing to shrimp farming did not occur as the farms were located in areas already under the influence of tidal water. Irrespective of whether shrimp farming took place or not, the area was already saline.

4.2.4. Pollution from aquaculture farms

In Kerala only improved traditional and extensive systems of culture practices are followed. As per the Coastal Regulation Zone (CRZ) Notification and subsequent amendments, the farmers are not going for intensive or semi-intensive culture practices in coastal zone. The stocking density, application of feed, feed additives, chemicals, drugs have all been reduced and thereby the pollution load discharged from the farms is also minimised.

4.3. Economic Analysis of Different Culture Practices

4.3.1. Improved traditional prawn filtration (seasonal)

The traditional practice of trapping juvenile prawns in *pokkali* fields by letting in water during high tide and letting out water during low tide was improved further by selective stocking with fast growing species like *P.monodon* and *P.indicus*, nursery rearing of PL, controlled feeding during early days with egg and sometimes with eradication in nursery area. As followed in the traditional practice the culture period was from November to April. Periodic harvest was done during the '*thakkom*', 2-3 days before and after every full moon and new moon day in the culture period. Complete harvest was done at the end of the culture period. Paddy cultivation (*pokkali*) is done during the monsoon period, but farmers are reluctant to do paddy cultivation these days because of escalated labour costs and less returns from paddy.

Twenty nine improved traditional seasonal prawn filtration farms in and around Parur, Nayarambalam and Ezhupunna were selected for the economic analysis. The size of the farms ranged from 3.5 to 138 acres. The average total cost of production per hectare was Rs. 55,309 /5 months (Middle of November to middle of April). This includes fixed cost of Rs.31,965 /ha/5 months and variable cost of Rs. 23,345 /ha/5 months. Fixed cost included lease value of the land (in the case of farms operated by lessee) or opportunity cost of the land (in case the farm is owner operated), interest at the rate of 13% on investment items like shed, pump, sluice gate, canoe and depreciation on items like shed, sluice gate, pump and canoe. (Depreciation is calculated adopting straight line method by dividing the cost of the item by its life span in years)

The production varied between 213 and 1569 kg ha^{-1} / 5 months. The average yield obtained was 821 kg ha^{-1}/ 5 months. The catch is dominated by *Metapenaeus dobsoni* (*thelly*) 65%, followed by *P. indicus* (Indian white shrimp) 21.4%, *P.monodon* (tiger shrimp) 13% and various fishes (0.6%) like pearl spot, tilapia, mullets etc. The average gross returns were Rs.76, 389 ha^{-1}/5 months. The average net profit was Rs. 21,080 ha^{-1}/5 months and the average net operating profit was Rs. 53,045 ha^{-1}/5 months. The average input–output ratio was 1.38. This means that for every rupee invested on improved traditional prawn filtration (seasonal) the additional or surplus returns realised was Rs. 0.38. A region wise comparison was made of farms in and around Parur, Ezhupunna and Nayarambalam and is given in Table-7.

Table-7. Comparative economics of seasonal shrimp farming (Improved traditional method) in Ezhupunna, Parur and Nayarambalam (2001-02)

ITEMS	EZHUPUNNA	PARUR	NAYARAMBALAM
Number of farms	2	21	6
Range of farm area (acres)	10-63	3.5-138	14-30
Total costs/ha/5 months (Rs)	55,824	75,598	46,746
Total fixed cost/ha/ 5 months(Rs)	31,932	34,370	31,277
Total variable costs /ha/ 5 months(Rs)	23,892	41,228	15,469
Labour cost/ha (Rs)	13,848	29,177	6,127
Feed cost/ha (Rs)	1,190	3,118	689
Seed cost/ha (Rs)	7,080	7,877	7,403
Average production / ha/ 5 months (kg)	759	1,085	949
Gross returns/ha/5 months(Rs)	72,545	1,02,000	81,309
Net profit /ha/5 months (Rs)	16,721	26,402	34,563
Net operating profit /ha/ 5 months(Rs)	48,653	60,772	65,840
Input–output ratio	1.30	1.35	1.74
Total cost of production/kg (Rs)	74	70	49
Revenue realised/kg (Rs)	96	94	86

Although farms in Parur area reported higher production, the results show that farms in Nayarambalam area was more profitable. This was due to the high labour cost and feed cost incurred in Parur than in Nayarambalam area. The cost of production per kg was lowest in Nayarambalam area due to lower labour cost and feed cost per ha. The intensity of additional feed given by the farmers in Nayarambalam area are comparatively less (23kg/ha as against 85 kg/ha and 94 kg/ha in Parur and Ezhupunna areas respectively) with least labour involvement except at the time of stocking and harvesting. When the average labour requirement per ha was 280 labour days in Ezhupunna region, it was103 in Parur and only about 50 in Nayarambalam.

During the survey period, white spot virus disease was so rampant that many of the farmers suffered huge economic loss. Mostly white spot virus attacked the crop on 50-55th day of stocking (as reported by the farmers). A comparison made on the economic aspects of disease affected and non affected farms is given in Table-8. The special feature noticed in the seasonal shrimp farms was immediate harvesting after the occurrence of disease. However the traditional filtration process continued till the completion of the season enabling the farmers to minimise the losses.

Table-8. Comparative economics of disease affected and non affected shrimp (seasonal-improved traditional method) farms (2001-02)

ITEMS	DISEASE AFFECTED		NON AFFECTED	
	Total	Per ha	Total	Per ha
Number of farms	9	-	20	-
Area (ha)	57.97	1	177.46	1
Total costs /5 months (Rs)	30,94,439	53,380	99,69,170	56,177
Total fixed cost /5 months(Rs)	19,77,125	34,106	55,01,437	31,001
Total variable cost / 5 months(Rs)	11,17,314	19,274	44,67,733	25,176
Labour cost (Rs)	5,49,903	9,486	26,66,869	15,028
Feed cost (Rs)	73,448	1,267	2,12,597	1,198
Seed cost (Rs)	3,78,370	6,527	13,31,837	7,505
Production / 5 months (kg)	27,304	471	1,73,556	978
Gross revenue / 5 months(Rs)	21,36,890	36,862	1,67,12,472	94,176
Net profit /5 months(Rs)	-9,57,549	-16,518	67,43,302	37,999
Net operating profit /5 months (Rs)	10,19,576	17,588	1,22,44,739	69,000

4.3.2. Improved traditional prawn filtration (perennial)

Perennial ponds were little deeper than seasonal ones and hence paddy could not be cultivated. In the improved perennial system, the only difference was that the filtration/culture was undertaken throughout the year. Sixteen perennial prawn filtration farms in and around Parur, Ezhupunna and Nayarambalam were surveyed for the present study. The size of the farms ranged from 2 to 160 acres. The production varied between 310 and 2088 kg ha^{-1} $year^{-1}$.

The total cost of maintaining one hectare of improved traditional perennial prawn filtration practice was Rs. 82, 589 ha^{-1} $year^{-1}$ which includes total fixed costs of Rs. 39, 377 ha^{-1} $year^{-1}$and total variable costs of Rs. 43,213 ha^{-1} $year^{-1}$. The average annual yield ha^{-1} was 779 kg. The catch is dominated by Indian white prawn *(Penaeus indicus)* (46.6%), followed by *thelly* (*Metapenaeus dobsoni)* (30%), tiger prawn (*Penaeus monodon)* (21%) and fishes like tilapia, mullets, milkfish etc. (2.4%). The average gross returns ha^{-1} $year^{-1}$ was Rs. 96, 773. The average net profit and net operating profit were calculated as Rs.14,184$ha^{-1}$$year^{-1}$ and Rs.53,560 ha^{-1} $year^{-1}$ respectively. The input – output ratio was 1.17.

A comparison made on the economic aspects of disease affected and non affected farms is given in Table-9. Most of the disease affected farms were having higher productivity records in previous years. Hence these farms were in high demand and commanded a higher lease amount. Thus the higher opportunity cost of these farms led to the higher fixed cost of disease affected farms. Feed and seed cost per ha was also higher in disease affected farms implying the high feed application and stocking density during the initial months, before disease onset.

Table-9. Comparative economics of disease affected and non affected shrimp (perennial - improved traditional method) farms (2001-02)

ITEMS	DISEASE AFFECTED		NON AFFECTED	
	Total	Per ha	Total	Per ha
Number of farms	3	-	13	-
Area (ha)	68.8	1	187	1
Total costs / year(Rs)	55,33,997	80,436	1,55,37,269	83,087
Total fixed cost / year(Rs)	31,80,899	46,234	70,67,665	37,795
Total variable cost / year(Rs)	23,53,098	34,202	84,69,604	45,292
Labour cost (Rs)	7,24,326	10,528	49,84,111	26,653
Feed cost (Rs)	4,82,907	7,019	6,94,518	3,714
Seed cost (Rs)	7,12,837	10,361	17,99,688	9,624
Production / year(kg)	36,727	534	1,56,276	836
Gross revenue / year(Rs)	56,21,304	81,705	1,87,46,750	1,00,250
Net profit / year(Rs)	87,307	1,269	32,09,481	17,163
Net operating profit / year (Rs)	32,68,206	47,503	1,02,77,146	54,958

A comparison of economic indicators of disease affected and non affected farms belonging to the improved traditional shrimp farming system is given in Table-10.

Table-10. Economic indicators of disease affected and non affected shrimp farms belonging to improved traditional category

KEY ECONOMIC INDICATORS	SEASONAL FARMS		PERENNIAL FARMS	
	DISEASE AFFECTED	NON AFFECTED	DISEASE AFFECTED	NON AFFECTED
Cost of production/ kg (Rs)	113	57	151	99
Revenue realised / kg (Rs)	78	96	153	120
Input-Output ratio	0.69	1.68	1.02	1.21

Table-10 shows that the disease affected ponds had higher cost of production (per kg) than non affected farms. Although the total cost per ha was less in disease affected farms than non affected ones, the lower production in the disease affected farms resulted in high production cost per kg. The revenue realised per kg in disease affected ponds was higher than the revenue realised per kg by non affected in the perennial farms. This was due to the fact that some shrimps survived the disease in affected farms were harvested at a bigger size later, fetched good price per kg, in spite of less total production. The economic indicators given in the table clearly highlights the huge economic loss incurred by disease affected farms.

4.3.3. Extensive culture systems

Extensive systems are relatively new farms compared to traditional ponds and are relatively smaller in area. Shrimp culture is done systematically on a scientific basis. Ponds are prepared before stocking. Eradication is done to kill unwanted organisms and predators. The hatchery reared seed is acclimatised to the pond environment slowly. The water quality parameters are monitored carefully. Artificial feed is given; either imported pellet feed or locally made compounded feed. Water exchange is done with pumps or through sluices. Aerators are also used in some farms. Complete harvest is done at the end of the culture period.2-3 crops are done in a season (October to May). Extensive systems stock either *P.monodon* seeds alone or *P.indicus* seeds alone or both the seeds and do not resort to natural stocking.

4.3.3.1. Extensive culture of *Penaeus monodon*

The data from 35 farms doing extensive culture of *Penaeus monodon* (tiger shrimp) in Ernakulam district and Kollam district were collected and analysed. The area of the farms ranged from 0.2 to 63 acres. Most of the farmers cultivated 2-3 crops/ season (October to May). The production varied between 224 and 1,746 kg ha^{-1}/season.

A comparison of the costs and returns data of extensive *Penaeus monodon* culture in Ernakulam district and Kollam district is given in Table-11. In Ernakulam district a further comparison is made between prawn culture in and around Chellanam, Parur and Panangad regions. Most of the farms in Kollam district were badly affected by white spot viral disease resulting in huge economic loss as indicated by negative returns. As a whole the farms in Ernakulam district showed profits ranging from Rs. 11,347 in Panangad to Rs. 54,262 in Chellanam region. While farms in Panangad and Chellanam areas fetched lease amounts of Rs. 36,500 and 33,800 per ha respectively, farms in Parur region fetched only 24,200 per ha. The investment on sluice gate, pump, shed etc. was also less in Parur region leading to low fixed cost per ha. The low fixed and variable cost in Parur region resulted into the lowest break even production of 457 kg as against 721 kg in Chellanam and 725 kg in Panangad and 910 kg in Kollam district. The average land lease per ha was Rs. 52,200 in Kollam district resulting in very high fixed cost. The size of farms observed in Kollam district was much smaller compared to Ernakulam district, which boosted up the production costs per ha due to intensive farming practices.

Table-11. Comparative economics of extensive tiger shrimp culture (Ernakulam and Kollam districts (2001-2002)

Items	Ernakulam District				Kollam District	Overall Average
	Panangad	Chellanam	Parur	Average		
Number of farms	10	8	2	20	15	35
Range of farm area (acres)	0.2-63	1.5-5	1.75-4	0.2-63	0.24-6	0.2-63
Total costs /ha/ 5 months (Rs.)	2,06,345	2,10,901	1,27,160	2,03,550	2,69,374	2,31,760
Total fixed cost/ ha/5months(Rs.)	52,811	52,448	35,727	52,264	83,666	65,722
Total variable cost /ha/5 months(Rs.)	1,53,534	1,58,453	91,433	1,51,286	1,85,708	1,66,038
Average production/ha/ 5 months (kg)	761	911	565	815	806	811
Breakeven production(kg)	721	725	457	712	910	796
Gross revenue/ ha/5months(Rs.)	2,17,692	2,65,163	1,56,827	2,33,438	2,38,758	2,35,718
Net profit /ha/5 months(Rs.)	11,347	54,262	29,667	29,888	-30,616	3,958
Net operating profit/ha /5 months (Rs.)	64,158	1,06,710	65,394	82,152	53,050	69,680
Input-Output ratio	1.06	1.26	1.23	1.15	0.89	1.02
Unit price realised (Rs./ kg)	286	291	278	286	296	291
Total cost of production / kg (Rs.)	271	232	225	250	334	286
Variable cost of production/ kg (Rs.)	201	174	162	186	230	205
Net profit/kg (Rs.)	15	60	53	37	-38	5
Net operating profit/kg (Rs.)	84	117	116	101	66	86

White spot disease affected many of the shrimp farms during the survey period. The profit and returns of disease affected and non affected farms under extensive system are given in Table-12. Six farms which ran in to losses due to other reasons like poaching, poor water quality and salinity fluctuations were omitted from this analysis.

Table-12. Comparative economics of disease affected and non affected extensive tiger shrimp culture (2001-02)

Items	Disease affected		Non affected	
	Total	Per ha	Total	Per ha
Number of farms	18	-	11	-
Area (ha)	34.81	1	31.41	1
Total costs /5 months(Rs)	78,55,433	2,25,666	62,95,192	2,00,420
Total fixed cost /5 months(Rs)	18,12,521	52,069	17,24,126	54,891
Total variable cost /5months(Rs)	60,42,912	1,73,597	45,71,066	1,45,529
Production / 5months(kg)	19,528	561	31,913	1,016
Gross revenue / 5 months(Rs)	59,54,564	1,71,059	92,15,882	2,93,406
Net profit /5 months(Rs)	-19,00,869	-54,607	29,20,690	92,986
Net operating profit /5 months(Rs)	-88,348	-2,538	46,44,817	1,47,877

The key economic indicators of disease affected and non affected extensive tiger shrimp culture are given in Table-13. In the farms categorised as disease affected, the virus onset was mostly on 50-55th day. The farmers either lost their entire crop or harvested what remained which were of lower grades. The farmers could get shrimps of higher grades which survived the disease towards the end of culture period, fetching them good price. The higher unit price realised in disease affected farms confirmed this factor. The variable cost was higher in the disease affected farms, the reason being their additional investment in seed and feed for a second or even a third crop compared to non affected farms.

Table-13. Key economic indicators of disease affected and non affected extensive tiger shrimp culture (2001-02)

Key economic indicators	**Disease affected**	**Non affected**
Breakeven production(kg)	740	693
Input-Output ratio	0.76	1.46
Unit price realised (Rs/kg)	305	289
Total cost of production /kg (Rs)	402	197
Variable cost of production /kg (Rs)	309	143
Net profit/kg (Rs)	-97	92
Net operating profit/kg (Rs)	-5	146

4.3.3.2. Extensive biculture of *Penaeus monodon* and *Penaeus indicus*

Six farmers doing extensive biculture of *Penaeus monodon* and *Penaeus indicus* in Chellanam in Ernakulam district and Pallithodu in Alappuzha district were surveyed and the data collected from them was analysed. The farms ranged from 0.84 to 7 acres and the production varied between 508 and 801 ha $^{-1}$ season^{-1}. The costs and returns of the biculture practice is given in Table-14. *P.monodon* contributed to 49% of the total shrimp production and *P.indicus* 51% in this culture system. The input output ratio was 1.05.

Table-14. Economics of extensive biculture of tiger and Indian white shrimp (2001-02)

Items	Extensive culture of tiger and Indian white shrimp	
	Total	Per ha
Area(ha)	9.09	1
Total costs /5 months(Rs)	11,10,735	1,22,193
Total fixed cost /5 months(Rs)	4,05,878	44,651
Total variable cost /5months(Rs)	7,04,857	77,542
Production /5months(kg)	5,709	628
Gross revenue / 5 months(Rs)	11,70,874	1,28,809
Net profit /5 months(Rs)	60,139	6,616
Net operating profit /5 months(Rs)	4,66,017	51,267

Some of the key economic indicators of disease affected and non affected farms under this biculture system is worked out and given in Table-15. The percentage contribution of *P.indicus* to the total shrimp production was 54% in disease affected farms whereas in non affected farms it was only 48%. The percentage contribution of *P.monodon* to the total shrimp production was 46% in disease affected farms whereas in non affected farms it was only 52%. Owing to their higher productivity in the previous years, the farms which were affected by disease in the present study were in high demand and hence the lease amounts of these farms were higher. The higher fixed cost in disease affected farms was due to this reason. The input-output ratio was 0.96 for disease affected culture systems and 1.14 for non affected systems.

Table-15. Comparative economics of extensive biculture of tiger and Indian white shrimp in disease affected and non affected farms (2001-02)

Items	Disease affected		Non affected	
	Total	Per ha	Total	Per ha
Number of farms	3	-	3	-
Area (ha)	5.61	1	3.48	1
Total costs /5 months(Rs)	6,28,325	1,12,001	4,60,703	1,32,386
Total fixed cost /5 months(Rs)	2,62,800	46,845	1,47,754	42,458
Total variable cost / 5 months(Rs)	3,65,525	65,156	3,12,949	89,928
Production /5 months (kg)	3,287	586	2,328	669
Gross revenue / 5 months(Rs)	6,01,897	1,07,290	5,23,141	1,50,328
Net profit /5 months(Rs)	-26,429	-4,711	62,438	17,942
Net operating profit /5 months(Rs)	2,36,372	42,134	2,10,192	60,400

4.3.3.3. Extensive monoculture of *Penaeus indicus*

Three farmers doing extensive culture of *Penaeus indicus* alone in Chellanam, Kumbalanghi and Malippuram in Ernakulam district were surveyed and details were collected on the costs and returns. The area of the farms ranged from 1 to 5.5 acres and production was in the range of 346-2,540 kg/ha/season. The economics of extensive *P.indicus* culture is given in Table-16.

Table-16. Economics of extensive culture of *P.indicus* (2001-02)

Items	Extensive culture of *P.indicus*	
	Total	Per ha
Area(ha)	4.73	1
Total costs /5 months(Rs)	4,04,207	85,456
Total fixed cost /5 months(Rs)	1,76,041	37,218
Total variable cost /5months(Rs)	2,28,166	48,238
Production/5months (kg)	6,736	1,424
Gross revenue / 5 months(Rs)	7,42,695	1,57,018
Net profit /5 months(Rs)	3,38,488	71,562
Net operating profit /5 months (Rs)	5,14,529	1,08,780

The key economic indicators of *P.indicus* culture system are given in Table-17.

Table-17. Key economic indicators of extensive culture system of *P.indicus*

Key economic indicators	Extensive culture of *P.indicus*
Input-Output ratio	1.84
Breakeven production (kg)	777
Total cost of production/kg (Rs)	60
Variable cost of production /kg (Rs)	39
Unit price realised (Rs/kg)	110
Net profit/kg (Rs)	50
Net operating profit/kg (Rs)	76

The economics is worked out separately for the disease affected and non affected farms and is presented in Table-18.

Table-18. Comparative economics of extensive Indian white shrimp culture in disease affected and non affected farms (2001-02)

Items	Disease affected		Non affected	
	Total	Per ha	Total	Per ha
Number of farms	1	-	2	-
Area (ha)	2.17	1	2.56	1
Total costs /5 months(Rs)	1,52,396	70,229	2,38,259	93,070
Total fixed cost /5 months(Rs)	75,611	34,844	98,317	38,405
Total variable cost / 5 months(Rs)	76,785	35,385	1,39,942	54,665
Labour cost (Rs)	58,625	27,016	1,19,555	46,701
Feed cost (Rs)	4,509	2,078	5,425	2,119
Seed cost (Rs)	6,013	2,771	4,884	1,908
Production / 5 months(kg)	751	346	5,025	1,963
Gross revenue / 5 months(Rs)	82,677	38,100	5,54,181	2,16,477
Net profit /5 months(Rs)	-69,720	-32,129	3,15,922	1,23,407
Net operating profit /5 months(Rs)	5,892	2,715	4,14,239	1,61,812

The key economic indicators of the culture are given in Table-19.

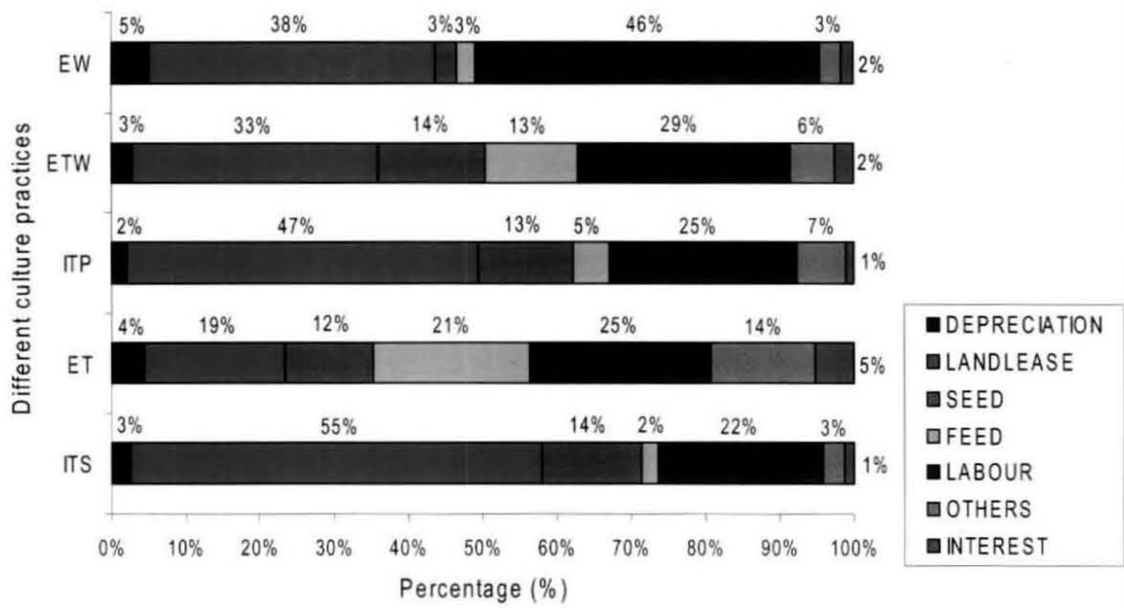
Table-19. Key economic indicators of extensive Indian white shrimp culture in disease affected and non affected farms (2001-02)

Key economic indicators	Disease affected	Non affected
Unit price realised (Rs/kg)	110	110
Breakeven production(kg)	638	846
Total cost of production/ kg (Rs)	203	47
Variable cost of production /kg (Rs)	102	28
Net profit / kg (Rs)	-93	63
Net operating profit /kg (Rs)	8	82
Input-Output ratio	0.54	2.33

Disease affected farm was located in Malippuram. Though production was only 346 kg in this farm, unit price was Rs 110, same as that of the non affected farms. This implies that the farmers could harvest prawns of higher grade in the affected ponds also although quantity harvested was less. Also the non affected farms incurred very high variable costs than the disease affected farms due to the high labour requirements. This high labour requirement in non affected farms was mainly for harvesting and feeding purpose. Although total cost of production was less for disease affected farms than non affected, the cost of production per kg was more. This was because of the low production in disease affected farms.

The low disease incidence and low production costs in Indian white shrimp extensive farms resulted in comparatively high net profits from these farms compared to other extensive shrimp farms. In general, improved traditional systems showed better profits and less disease incidence than extensive systems. The high stocking density in the extensive farms resulted in more stress among the shrimps and hence they were more susceptible to viral attack.

The proportionate contribution of various items of expenditure towards total cost of farming in different shrimp culture systems is given in Figure-5.



ITS Improved traditional (Seasonal)
ET Extensive tiger shrimp culture
ITP Improved traditional (Perennial)
ETW Extensive culture of tiger shrimp and Indian white shrimp
EW Extensive culture of Indian white shrimp

Figure-5. Percentage cost structure in different shrimp culture practices

In the improved traditional systems, land lease or the opportunity cost of the land contributed nearly to 50% of the total cost. In extensive systems, labour and feed accounted for approximately half of the total cost of farming. Seed contributed to 14-15% of the total cost in all the systems except in extensive culture system of *P.indicus* where seed cost was only 3% of the total cost.

For all comparisons of inputs and outputs, the data from farms not affected by disease alone is taken. A comparison of various inputs used in different shrimp culture practices is given in Table-20.

Table –20. Comparative input utilisation in different shrimp culture practices

Type of Culture practice	Labour (labour days/ ha)	Feed (kg/ ha)	Total Operating cost (Rs.)/ ha
Improved traditional prawn filtration (seasonal)	118	79	56,177
Improved traditional prawn filtration (perennial)	206	250	83,087
Extensive tiger shrimp culture	340	2,320	2,00,420
Extensive Indian white shrimp culture	345	1,367	93,070
Extensive culture of both tiger shrimp and Indian white shrimp	405	934	1,32,386

In shrimp culture practices the most important inputs used are labour, feed, seed, fuel and miscellaneous items. Since labour and feed are highly significant in all types of farming systems both are considered for comparative purpose. However the total operating cost for all systems are also given for the overall comparison between various farming practices. All the input requirements in the extensive systems are higher than the improved traditional systems. Maximum labour requirement was observed for extensive biculture system and maximum feed requirement for extensive tiger shrimp culture.

A comparison of the costs of different inputs used per kg of the produce in different culture practices is given in Table-21. For calculating land cost, only the opportunity cost of the land is taken in the case of owner operated farms and lease amount in the case of lessee operated farms.

Table-21. Cost structure of inputs in different shrimp culture practices (Rs./kg)

Type of Culture practice	Cost /kg produce (Rs./kg)					
	Labour	Feed	Seed	Land	Others	Total
Improved traditional prawn filtration (seasonal)	15.37	1.23	7.67	30.90	2.27	57.44
Improved traditional prawn filtration (perennial)	31.89	4.44	11.52	49.53	2.01	99.39
Extensive tiger shrimp culture	49.73	44.08	29.97	36.89	36.59	197.26
Extensive Indian white shrimp culture	23.79	1.08	0.97	16.67	4.9	47.41
Extensive culture of both tiger shrimp and Indian white shrimp	72.64	24.85	21.43	45.47	33.5	197.89

When input cost per unit of output was compared across the different systems, labour cost, feed cost and seed cost were higher in extensive systems than in improved traditional systems except for the extensive culture system of *P.indicus*. The low feed cost was due to the usage of locally made feed for *P.indicus* by most of the farmers. Improved traditional (perennial) system had higher land cost than all the extensive systems. The comparatively higher land cost for the perennial system was due to the fact that the pond was used for culture throughout the year. The input cost per kg of output was the least for the extensive system of *P.indicus* among the different extensive culture systems.

A comparison using partial productivity ratios of different inputs used in various culture practices is given in Table-22. The total operating cost is considered for calculating productivity of capital.

Table-22. Partial productivity ratios of different inputs for different shrimp culture practices

Culture practice	Productivity ratios			
	Labour (kg/ labour-day)	**Land (kg/ha)**	**Feed (kg/kg)**	**Capital (kg /Rs.)**
Improved traditional prawn filtration (seasonal)	8.29	978	-	0.017
Improved traditional prawn filtration (perennial)	4.06	836	-	0.010
Extensive tiger shrimp culture	2.99	1,016	0.44	0.005
Extensive Indian white shrimp culture	5.69	1,963	1.44	0.021
Extensive culture of both tiger shrimp and Indian white shrimp	1.65	669	0.72	0.005

When output produced per unit input consumed was analysed, it was seen that all the extensive systems except for the culture of *P.indicus* had lower productivity of labour and capital than the improved traditional systems. The productivity of feed in the improved systems was not given as it showed exceptionally higher values which are infact not realistic as shrimps in these farms fed not only on the artificial feed supplied but also on the natural food available in the ecosystem. Productivity of capital, feed and land was highest for extensive system of *P.indicus*. As far as partial productivity values are considered, the extensive culture system of *P.indicus* was giving best results.

4.3.4. Crab culture

Crab culture is undertaken in smaller ponds for 6 months period. Bamboo fencing with overhanging net is done to prevent their escape over the dyke. Dykes are strengthened to prevent the escape of crabs through the holes. Baby crabs are collected from the wild and are stocked in the pond. They are fed with fresh trash fish or salted fish. Complete harvest is done using lift nets or by hand picking at the end of the culture period.

Sixteen farmers doing crab culture in Vallarpadom Island and in Valappu and Edavanakkad regions of Vypeen Island were surveyed and data on costs and returns of crab culture was collected. The culture was done for a period of four to six months (August/September to February) when the salinity was conducive for the culture. The size of the farms ranged from 0.1 to 1.6 acres. The production ranged from 368 to 1,143 kg/ha/ 6 months.

4.3.5. Crab fattening

Crab fattening is rearing of soft shelled crabs (water crabs) for short periods of 2- 4 weeks until their shell gets hardened. The pond preparations are the same as crab culture. Hide-outs are given in the pond bottom for the water crabs to hide themselves.

Eight farmers in and around Ernakulam district (Kumbalanghi, Munambam, Cherai, Nayarambalam and Murikkumpadom) doing crab fattening on a continuous basis through out the year (twelve crops of two to four weeks duration) were selected for the study. The area of the farms ranged from 0.1 to 2 acres. The yield per ha per six months ranged from 2,064 to 10,668 kg (average 5.423 t /ha/6months).

The economics of crab culture and crab fattening is given in Table-23. The economics of crab fattening has been worked out for 6 months only for maintaining uniformity in crop duration for both types of operations for easy comparative assessment.

Table-23. Comparative economics of crab culture and fattening (2001-02)

Items	**Crab culture (per crop of 6 months)**		**Crab fattening (6 months)**	
	Total	**Per ha**	**Total**	**Per ha**
No. of crops	1	-	6	-
Area(ha)	2.78	1	2.22	1
Total costs (Rs)	4,69,623	1,68,929	20,96,616	9,44,422
Total fixed cost (Rs)	56,537	20,337	1,09,490	49,320
Total variable cost (Rs)	4,13,086	1,48,592	19,87,126	8,95,102
Production (kg)	2,241	806	12,039	5,423
Gross revenue (Rs)	5,91,893	2,12,911	32,91,503	14,82,659
Net profit (Rs)	1,22,270	43,982	11,94,886	5,38,237
Net operating profit (Rs)	1,78,807	64,319	13,04,377	5,87,557

The key economic indicators of crab culture and fattening systems are given in Table-24. To achieve break-even production 79.4% and 63.8% of the total output produced in crab culture and crab fattening practices respectively were sufficient. This coupled with the input-output ratios and profit per kg showed that crab fattening was highly profitable and less risky compared to crab culture. Commercial hatchery production of crab seed will help a long way in the wide spread adoption of this culture practice.

Table-24. Key economic indicators of crab culture and crab fattening systems

Key economic indicators	Crab culture	Crab fattening
Input-Output ratio	1.26	1.57
Unit price realised (Rs/kg)	264	273
Breakeven production(kg)	640	3,459
Total cost of production /kg (Rs)	210	174
Variable cost of production / kg (Rs)	184	165
Net profit/kg (Rs)	55	99
Net operating profit/kg (Rs)	80	108

4.3.6. Milkfish culture

Milkfish culture is conducted for four to five months in brackish water ponds. Seed obtained from seed collectors are stocked in the pond. Some farmers have stocked seeds collected even from Mandapam area of Tamil Nadu. They are fed with rice bran, rice, groundnut oil cake etc. Harvest is done using cast nets. Drain harvest is also carried out.

Three milkfish farms, one each in Valappu and Elamkunnappuzha in Vypeen Island and in Vallarpadom Island were observed. The culture was undertaken for a period of four to five months. The size of the farms ranged from 0.16 to 10 acres. The stocking density varied from 3,969 to 12,700 seeds per hectare. The yield per ha per crop ranged from 698.5 to 2,794 kg. The details of cost and returns are given in Table-25.

Table-25. Economics of milkfish culture in Ernakulam district of Kerala (2001-02)

Items	Milkfish culture	
	Total	Per ha
Area(ha)	4.63	1
Total costs / crop (Rs)	3,38,231	73,052
Total fixed cost / crop(Rs)	44,457	9,602
Total variable cost / crop(Rs)	2,93,774	63,450
Production / crop(kg)	8,084	1,746
Gross revenue / crop(Rs)	5,12,059	1,10,596
Net profit / crop (Rs)	1,73,828	37,544
Net operating profit / crop (Rs)	2,18,285	47,146

The key economic indicators of milkfish culture are given in Table-26. The break even production worked out in the present study forms only 66.44% of the total production indicating relatively less risk involved in milkfish farming. The input-output ratio of 1.51 showed the high profitability of milkfish culture. Milkfish culture does not require much input. It can be undertaken as a small family venture. Even then milkfish culture is not picking up to the expected level. The people are more attracted to shrimp culture for the higher price it fetches. The relative difficulty in getting the seed is also another factor for lesser adoptability. Farmers are even going up to Mandapam in Tamil Nadu to procure seed. Hatchery for milkfish has to be established commercially for propagating this culture practice.

Table-26. Key economic indicators of milkfish culture

Key economic indicators	Milkfish culture
Input-Output ratio	1.51
Unit price realised (Rs/kg)	63
Breakeven production(kg)	1,160
Total cost of production /kg (Rs)	42
Variable cost of production /kg (Rs)	36
Net profit/kg (Rs)	22
Net operating profit/kg (Rs)	27

The percentage contribution of various items of expenditure towards total cost in crab culture, crab fattening and milkfish culture is given in Figure-6. In crab fattening, seed alone contributed to 70% of the total cost. Labour and feed contributed to 56% of the total cost in crab culture. Labour and seed contributed to 70% of the total cost in milkfish culture.

Revolutionary changes are taking place in the production systems in the inland (fresh water) sector. The production was more or less doubled in the inland sector during the last decade. In the marine/ brackish water sector, the scope lies in the intensification of the finfish culture rather than concentrating on shrimp culture alone.

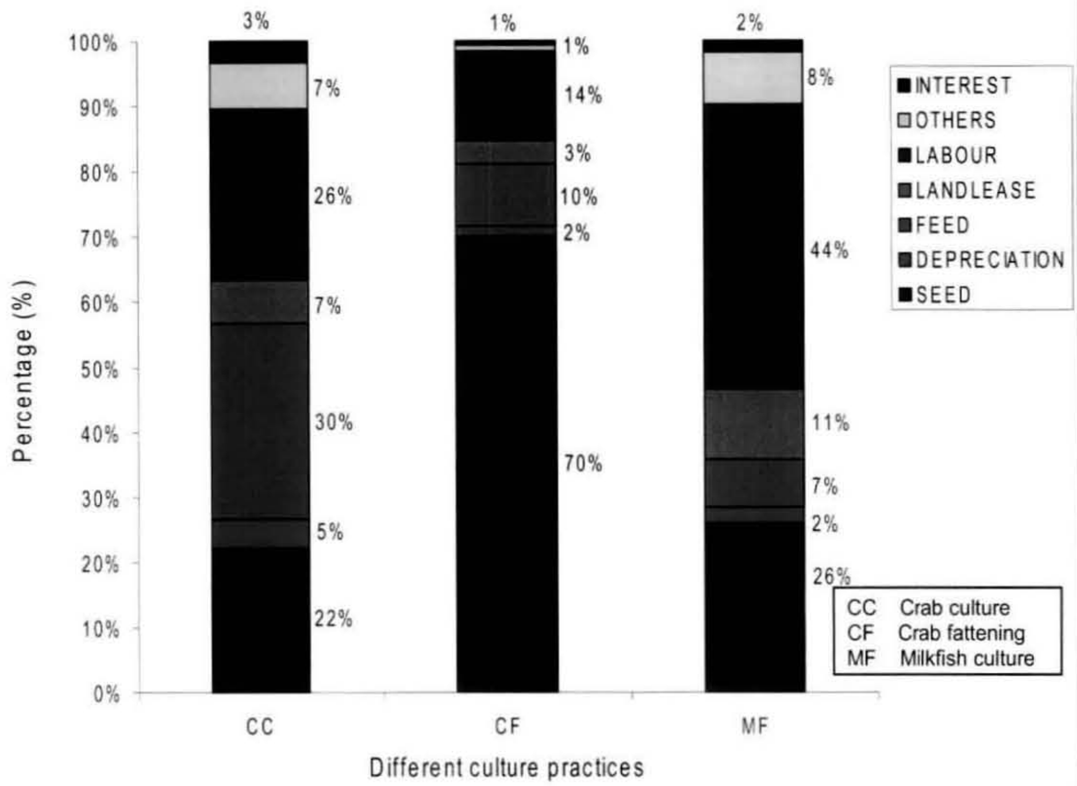


Figure-6. The percentage cost structure of crab culture, crab fattening and milkfish culture

4.3.7. Polyculture systems

Polyculture systems grow more than one species. Care should be taken while selecting the species so that they are compatible with each other. Shrimp, fishes, crabs and seaweed can be stocked in the pond in different combinations and stocking densities. Polyculture practices are more efficient than monoculture systems as it utilises the available inputs in a more efficient way.

In the polyculture system of fishes, milkfish (*C. chanos*), grey mullet (*M. cephalus*), mullets, Asian sea bass (*L. calcarifer*) and tilapia culture were considered. Seeds of these fishes are obtained from the wild collectors. Fishes are fed with rice, rice bran and locally made feeds. Tilapia is grown with sea bass as forage species. Polyculture of mullets, milk fish, tilapia, sea bass conducted by three farmers was selected for the study. The farms were located in Puduvypu and Malippuram of

Vypeen Island. The size of the farms ranged from 0.24 to 0.5 acres. The production ranged from 1,626 to 9, 072 kg/ha/crop. The culture period extended from six to ten months (Table-27).

Four farmers doing polyculture of mud crab, shrimp (tiger shrimp and Indian white shrimp) and fishes (mullets, milkfish, tilapia, sea bass) were selected for the study. The farms were located in Vypeen Island in places like Cherai, Puduvypu and Azhikode near Munambam. The culture period extended from four to seven months. The size of the farms ranged from 0.25 to 1.15 acres. The production ranged from 2,032 to 10,287 kg/ha/crop (Table-27).

Twelve farmers doing polyculture of fishes (mullets and milk fish) and shrimp (tiger shrimp and Indian white shrimp) in Valappu, Edavanakkad, Elamkunnappuzha, Malippuram and Kuzhupilly of Vypeen Island were randomly selected for the study and details on economics were collected. The culture period extended from six to twelve months. The farms ranged in size from 0.17 to 10 acres. The production ranged from 697to 8,868 kg/ ha/crop (Table-27).

Table-27. Comparative economics of different polyculture practices (2001-02)

Items	Polyculture of crab, fish and shrimp	Polyculture of fish and shrimp	Polyculture of fishes
Total costs /ha/ crop (Rs)	4,74,224	1,61,731	2,01,168
Total fixed cost/ha/ crop(Rs)	49,039	48,737	13,574
Total variable cost /ha/ crop(Rs)	4,25,185	1,12,993	1,87,593
Average production/ ha / crop (kg)	4,935	2,721	5,647
Gross revenue/ha/ crop(Rs)	7,88,886	3,11,084	4,03,437
Net profit / ha / crop (Rs)	3,14,662	1,49,353	2,02,269
Net operating profit / ha / crop (Rs)	3,63,701	1,98,091	2,15,844
Input-Output ratio	1.66	1.92	2.01

Profits were higher for the polyculture system with shrimp, crabs and fishes, followed by the polyculture system with fishes. The polyculture systems in general had higher input-output ratios than the monoculture systems.

A comparison of percentage contributions of various items towards total cost of farming of the different polyculture systems is given in Figure-7.

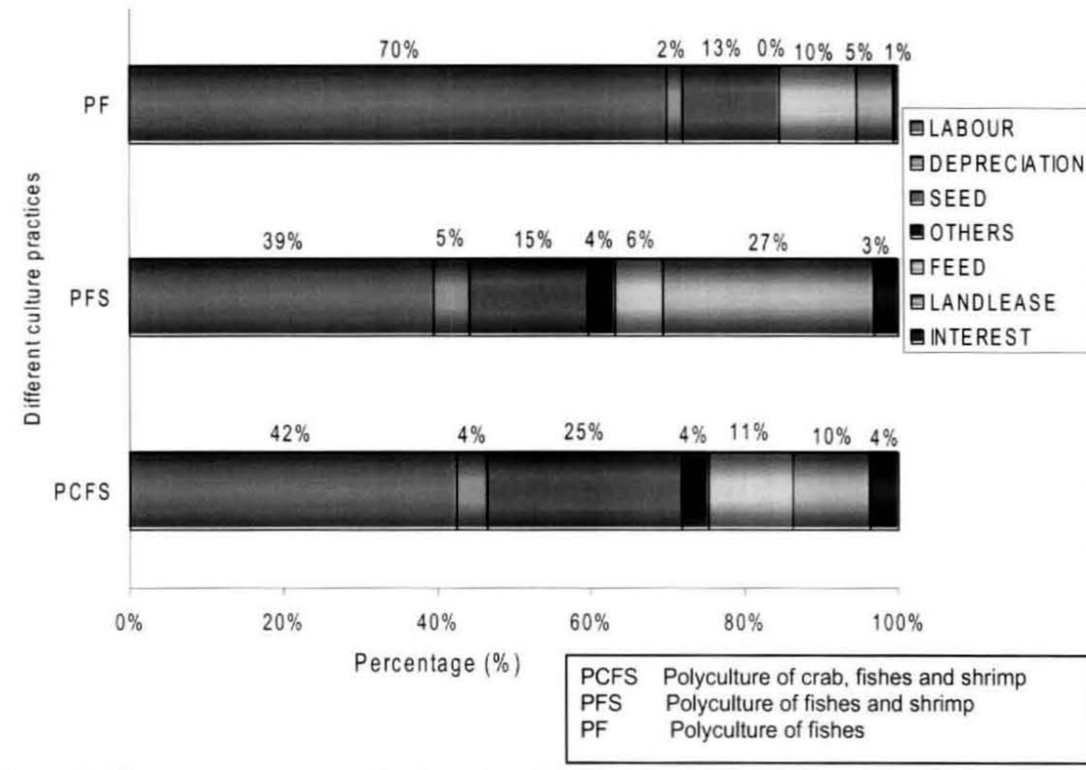


Figure-7. The percentage contribution of various items towards total cost of farming in different polyculture systems

Labour was the single largest contributor to total cost in all the three polyculture systems. The percentage contribution of land lease was the least in the polyculture system of fishes, showing less demand of land suitable for culture of fishes alone. These ponds were located mostly in remote areas having comparatively less water exchange facility.

The partial productivity ratios of land, labour, feed and capital are compared across the different culture systems and are given in Figures 8 to 11.

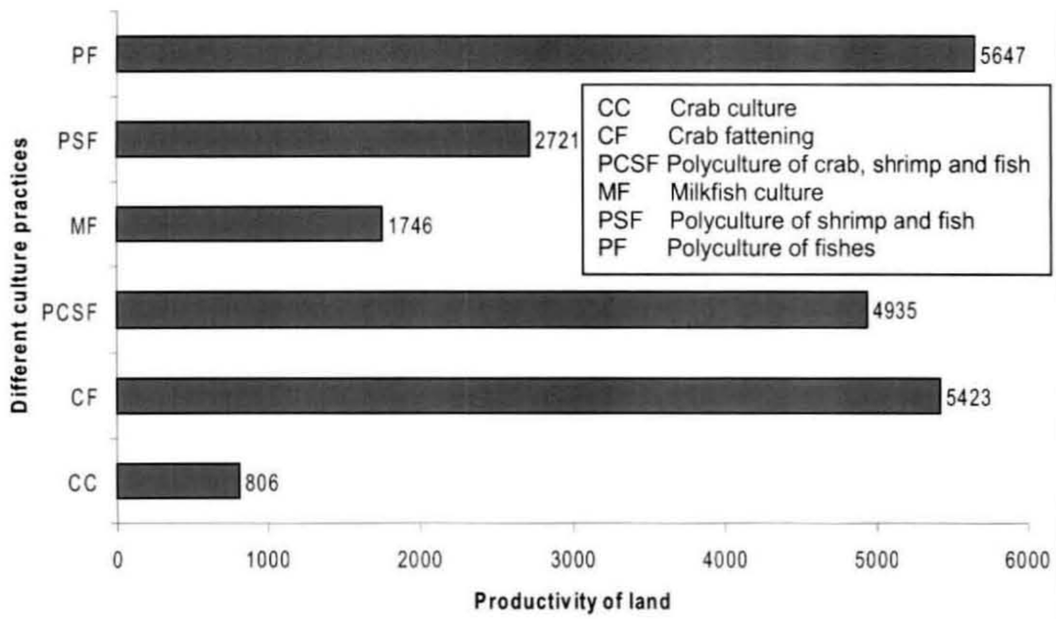


Figure-8. Productivity of land(ha) in different culture practices

The productivity of land was highest for polyculture system with fishes and lowest for crab culture system. The crab fattening system had the next higher value. This itself explains the increasing interest for crab farmers to do fattening rather than going for culture operations. In the crab fattening system, six to ten crops could be conducted in six months and the size of the seed at the time of stocking is above 350 g. Although the growth increment is marginal, all crabs weigh above 350 g each at the time of harvest. This accounts for the high productivity of land in the system. The price of one kg of excel grade mud crab(more than 850g) was in Rs. 280-320 range and that of big grade (more than 550g) was Rs. 180-220 and Rs. 90-110 range for medium grade (more than 350 g). In the crab culture system, owing to the lack of naturally available seed and conducive salinity, only a single crop is carried out in a year, that too of six months duration. This explains the low productivity of the system.

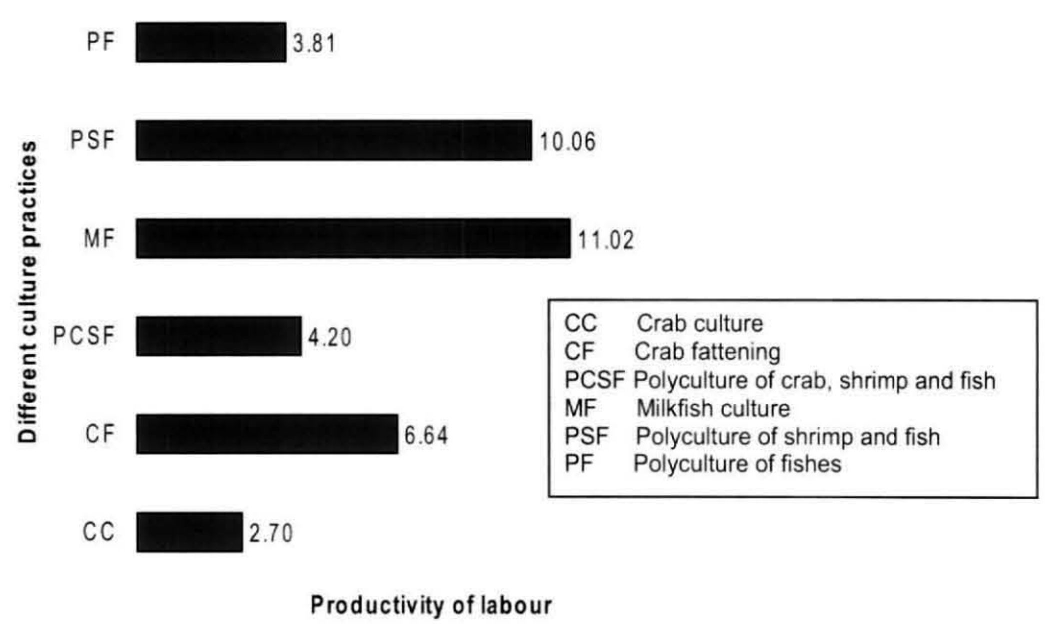


Figure-9. Productivity of labour of different culture practices

Productivity of labour is highest for milkfish culture system implying less labour requirement. Milkfish culture requires labour input during the initial pond preparation and stocking time and during the harvest time unlike other species which require constant attention throughout the culture period for feeding and water quality management. Thus milkfish culture which is less risky and reasonably profitable is suitable as a small family venture.

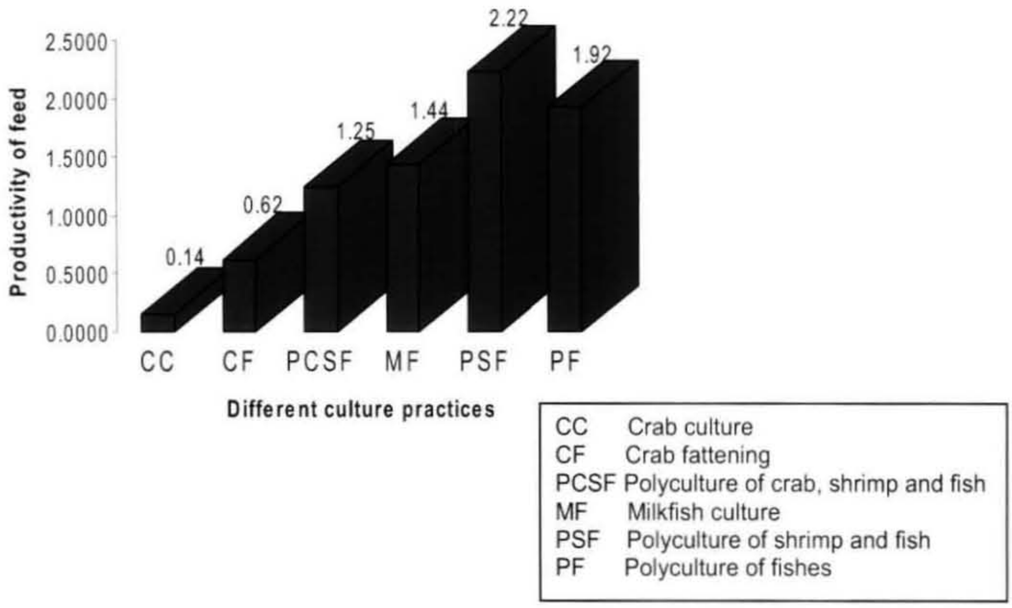


Figure-10. Productivity of feed in different culture practices

Productivity of feed for the different culture systems indicates high efficiency for milkfish culture system and polyculture systems. This was due to the fact that in polyculture systems and milkfish culture system, feed was given in very low quantity and the cultured organisms depended on natural food to a great extent.

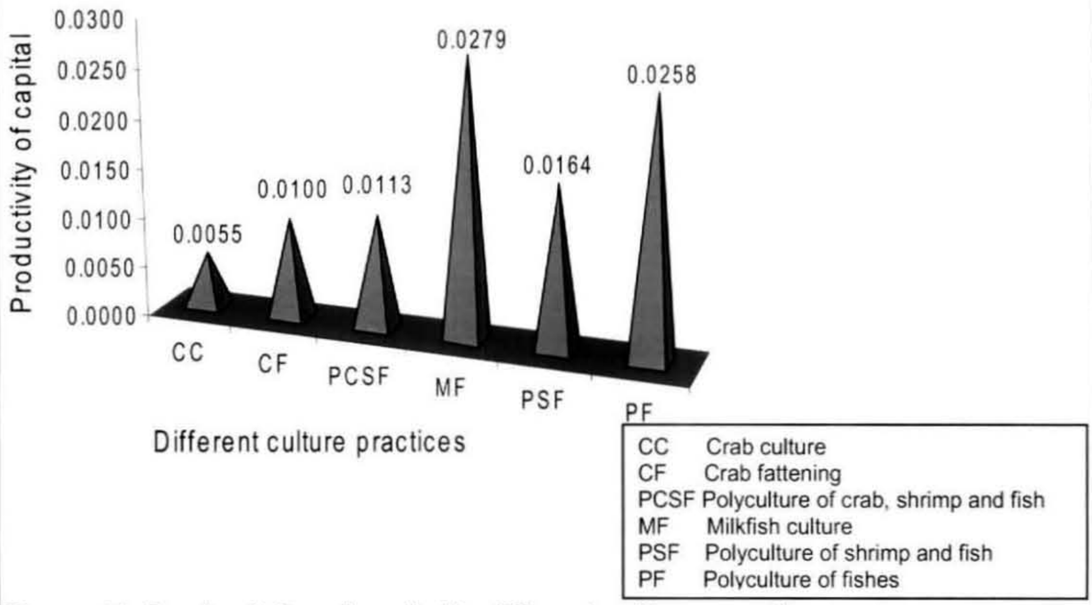


Figure-11. Productivity of capital in different culture practices

The fish culture systems (both polyculture of fishes and milkfish monoculture) give the highest productivity of capital, followed by other polyculture systems. The operating cost required for milkfish culture was the least of all, which explains the high productivity of capital for the system. Except for land and labour, productivity of all other inputs are higher for milkfish and polyculture systems.

A comparison of the cost of different inputs used (labour, feed, seed and land) per unit of output for different culture practices (crab culture, crab fattening, polyculture of crab, shrimp and fish, milkfish culture, polyculture of shrimp and fish and polyculture of fishes) is given in Figure-12.

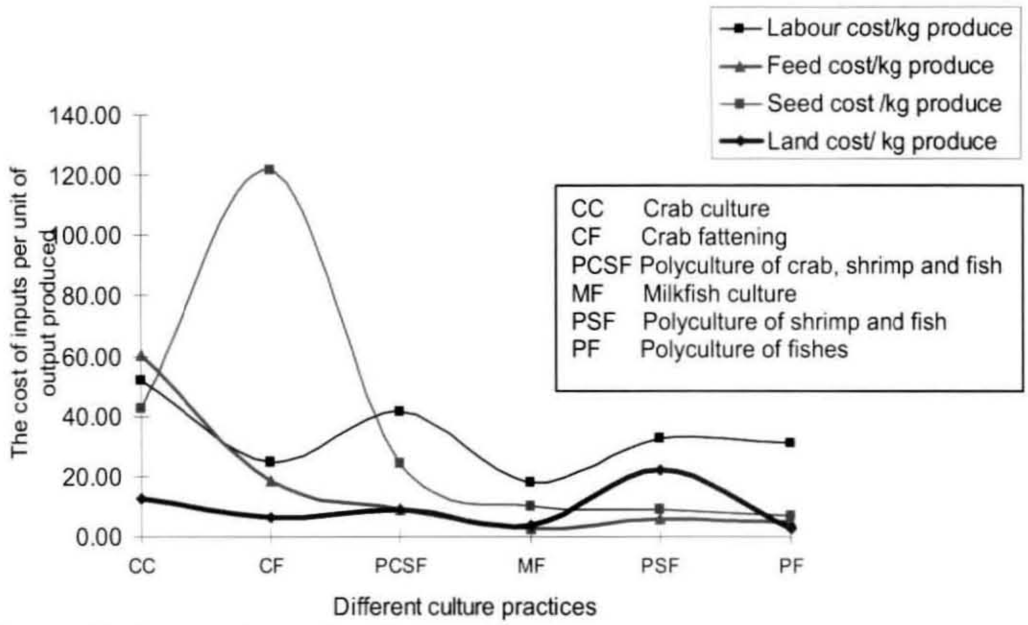


Figure-12. Comparison of unit cost of production in different culture practices

Crab culture tops in labour and feed costs per unit of output produced. Crab fattening has the highest seed cost, followed by crab culture. Land cost is highest for the polyculture system with shrimp and fish as components. Among polyculture systems, the ones with shrimp as one of the components have higher input costs than one with fishes alone. Land cost is higher in the systems with shrimps than those with fishes, showing the high demand for land suitable for shrimp culture. Labour requirement is also higher for the polyculture systems with shrimp than the fish culture systems. While fish culture system uses rice and other locally available cheap feeds, the systems with shrimp as one of the components utilises costly pellet feed or locally made feed, costlier than fish feeds.

The operating cost required per ha for different culture practices (crab culture, polyculture of crab, shrimp and fish, milkfish culture, polyculture of shrimp and fish and polyculture of fishes) is depicted in Figure-13. Crab fattening system is treated separately owing to the higher values.

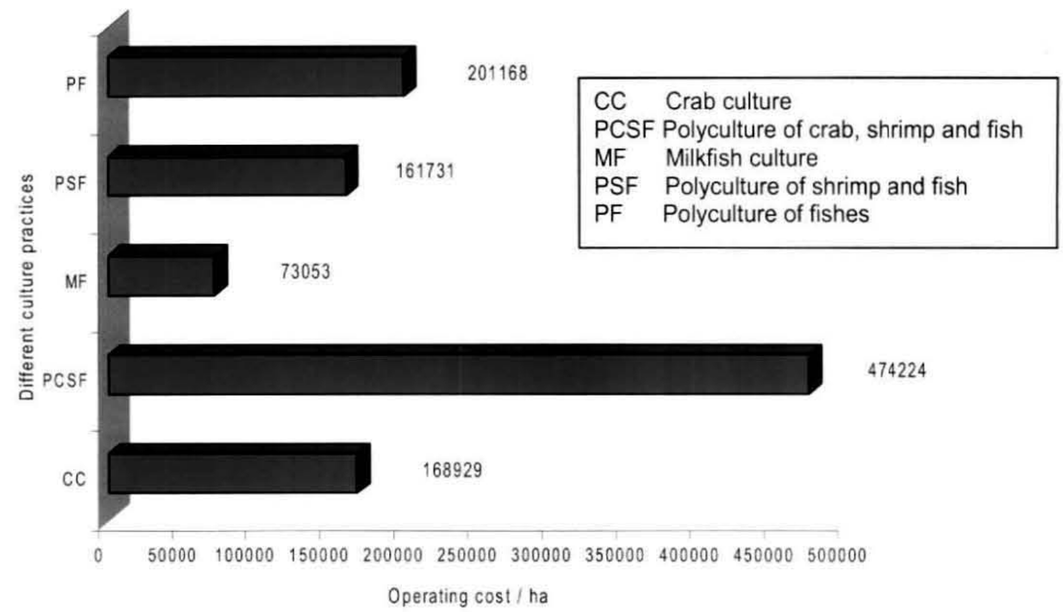


Figure-13. Operating cost/ha for different culture practices

The operating costs per ha is maximum for polyculture system with crab, shrimp and fish and minimum for milkfish culture system. The milkfish is having minimum input requirement than other culture practices and therefore the total operating cost is reduced to a minimum. The labour required in days per ha for different culture practices is given in Figure-14.

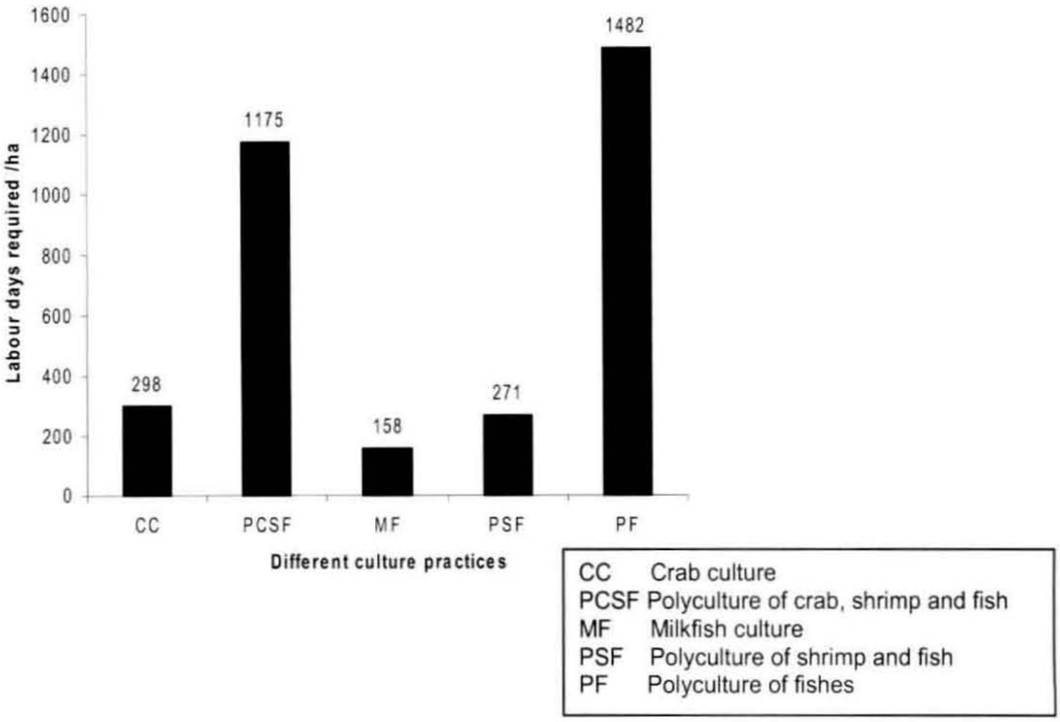


Figure-14. Labour-days required/ha for different culture practices

Polyculture system with fishes has the highest labour requirement and milkfish culture system the lowest. In milkfish culture, apart from the pond preparation and stocking stage initially and the harvesting stage finally, not much of a care is required. Feeding is done on a minimum basis, that too with locally available rice bran, groundnut oil cake, rice etc. Figure-15 shows a comparison of feed requirement for different culture practices.

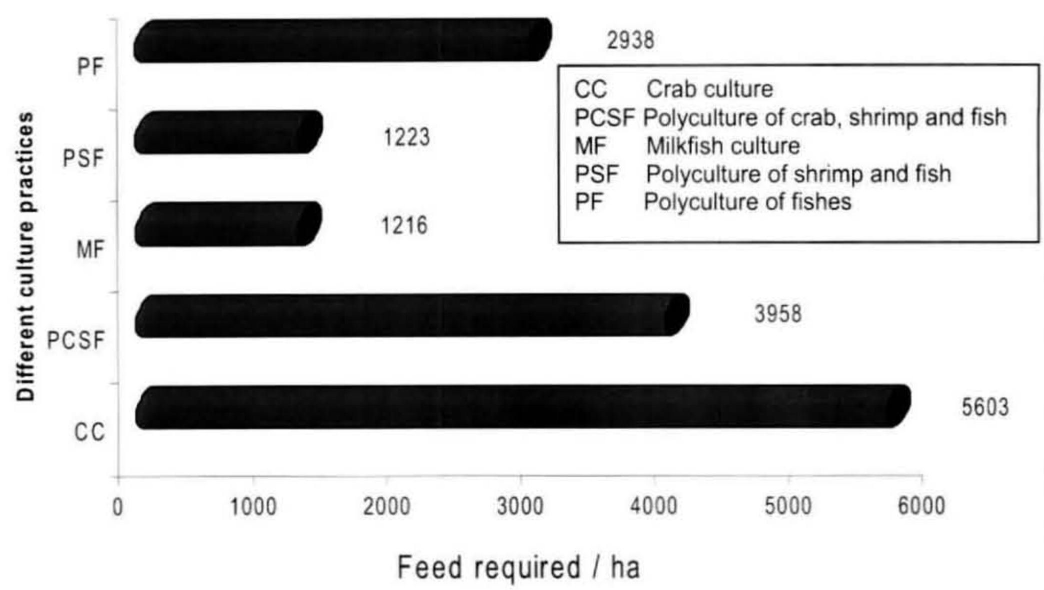


Figure-15. Feed requirement for different culture practices

The crab culture system has the highest feed requirement and milkfish system the least.

The crab fattening system incurred an operating cost of Rs. 18,70,124 /ha. The feed requirement /ha was 8,722 kg and the labour requirement was 817 labour-days/ha. In crab fattening system, feeding and water quality management have to be done on a daily basis throughout the culture period, making the culture system labour intensive. Culling (putting uniform sized crabs together and removing others, to prevent cannibalism among them), providing shelters (tiles, tree branches, pipes etc.) for soft shelled crabs, selective harvesting of hardened crabs are all required in crab fattening unlike in crab culture, making it labour intensive. The weight of the water crabs used as seed in crab fattening is much higher than the seed used in crab culture. Crabs have to be fed with chopped trash fish daily at 10% of the body weight. Occasionally salted fish is also given. For this reason, feed requirement per ha is also higher here compared to crab culture. The milkfish system has the lowest requirement for all the inputs. Except for labour, crab fattening system tops in all other input requirements.

4.3.8. Rack and ren culture of edible oyster

Rack and ren system is followed for edible oyster culture. Racks are installed in the backwaters and ropes with oyster shells are suspended from them at the appropriate time (November-December). The natural spat attaches itself to the oyster shells and grows on them. Periodic thinning is done as the oyster grows to promote their growth. Periodic cleaning is done to remove predators and borers. As oysters are filter feeders they feed on the naturally available food organisms in the water. After eight to nine months they are harvested by lifting the ropes. Some farmers depurate the oysters before marketing to reduce the pollution load in the oyster. Meat is shucked from the shell and sold.

Details on the edible oyster culture were collected from twenty two farmers doing the culture in Ayiramthengu, near Kayamkulam in Kollam district of Kerala. The culture extended from November/ December to September/October (eight to nine months). The production from a single unit ranged from 136 to 378 kg/ eight to nine months. The farm area ranged in size from 150 to 500 m^2. The average farm area worked out to be 300 m^2. The average total cost was Rs. 9, 572/ unit.

The percentage contribution of various items to the total cost is given in Figure-16. Labour alone accounted for 61%of the total cost. Labour is required for the installation of rack, making ren by drilling oyster shells, in the initial stages. Cleaning of the shell, thinning (the oysters have to be thinned down as they grow bigger), removing predators and borers have to be done throughout the culture period. Harvesting is also labour intensive. The edible oyster meat is sold after shucking, which is also labour intensive.

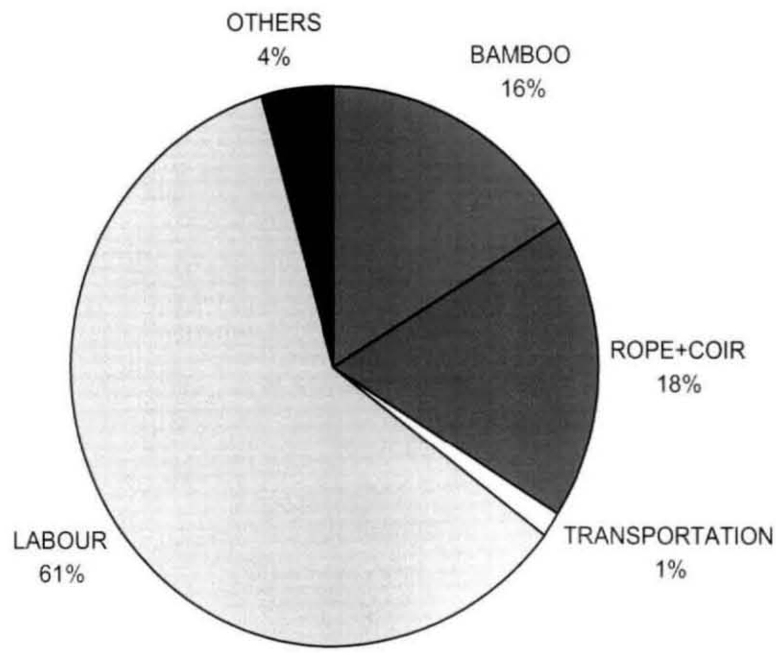


Figure-16. Cost structure of edible oyster culture

4.3.9. Rack and rope culture of mussel

Rack and rope system is followed for mussel culture. Rack is installed in the back water. Mussel seeds are collected from seed collectors and wrapped around the rope covered by bandage cloth. Ropes are suspended from rack. By the time mussel seed attaches itself to the rope, the bandage cloth would worn off. Periodic thinning and cleaning is required to ensure proper growth and survival. Ropes are lifted after seven to eight months and the produce is sold.

Twenty nine farmers doing rack and rope culture of mussels in Padanna and Ori regions of Kasargod district were surveyed and details were collected on their culture practice. The culture extended from November-December to May/June. The production from a single unit ranged from 2 to 24 tonnes. The area of a single unit ranged from $200m^2$ to $800m^2$ (5 to 20 cents) with an average of 500 m^2. The average number of strings suspended from a single unit was 500.

The total cost / unit was Rs. 24, 259 and item wise split up of various expenses in total cost is given in Figure-17. Though labour is the single largest item, the percentage is much less than that of edible oyster. Unlike in edible oyster, drilling the shell and shucking the meat from shell are not done here, which are labour intensive. Here seed also contributes significantly to the total cost. In edible oyster, the seed settles naturally on the cultch material (Oyster shells drilled and suspended from ren). In mussel culture, seed has to be purchased from local collectors and were seeded manually and suspended from the rack.

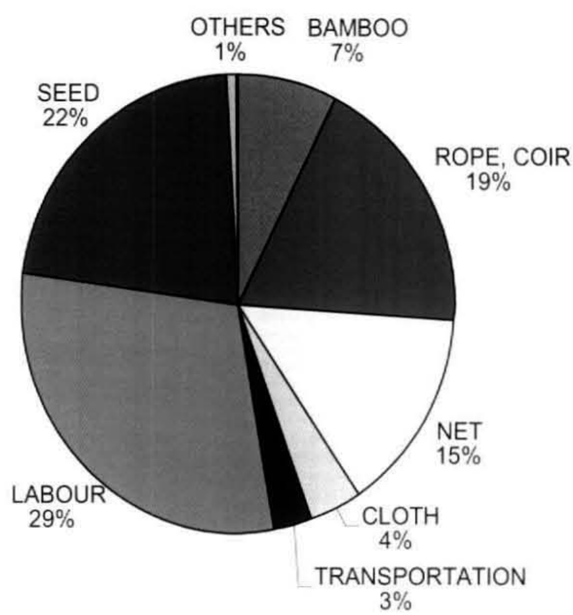


Figure-17. Cost structure of rack and rope culture system of mussel

The economics of edible oyster and mussel culture practices is given in Table-28.

Table-28. Comparative economics of edible oyster culture and mussel culture (2001-02)

Items	**Edible Oyster culture**	**Mussel culture**
Total cost / unit (Rs)	9,572	24,259
Total fixed cost / unit (Rs)	1,617	1,939
Total variable cost / unit (Rs)	7,955	22,320
Production / unit (kg)	3493	6,772
Breakeven production(kg)	2,393	4,411
Revenue/ unit (Rs)	13,973	37,248
Net profit / unit (Rs)	4,401	12,989
Net operating profit/ unit (Rs)	6,018	14,928
Total cost of production /kg (Rs)	2.74	3.58
Variable cost of production /kg (Rs)	2.28	3.30
Unit Price realised (Rs/kg)	4.00	5.5
Net profit / kg (Rs)	1.25	1.92
Net operating profit /kg (Rs)	1.72	2.20
Input-Output ratio	1.46	1.54

Heat shucked meat constitutes 8 % of the total shell on weight of edible oyster. One kg of edible oyster shucked meat fetches a price of Rs. 50. For comparative purpose, the price of shell on oyster is taken. Profit is found to be higher for a unit of mussel culture than for a single unit of edible oyster culture. A comparison of productivity of labour and capital of oyster and mussel culture is given in Figure-18.

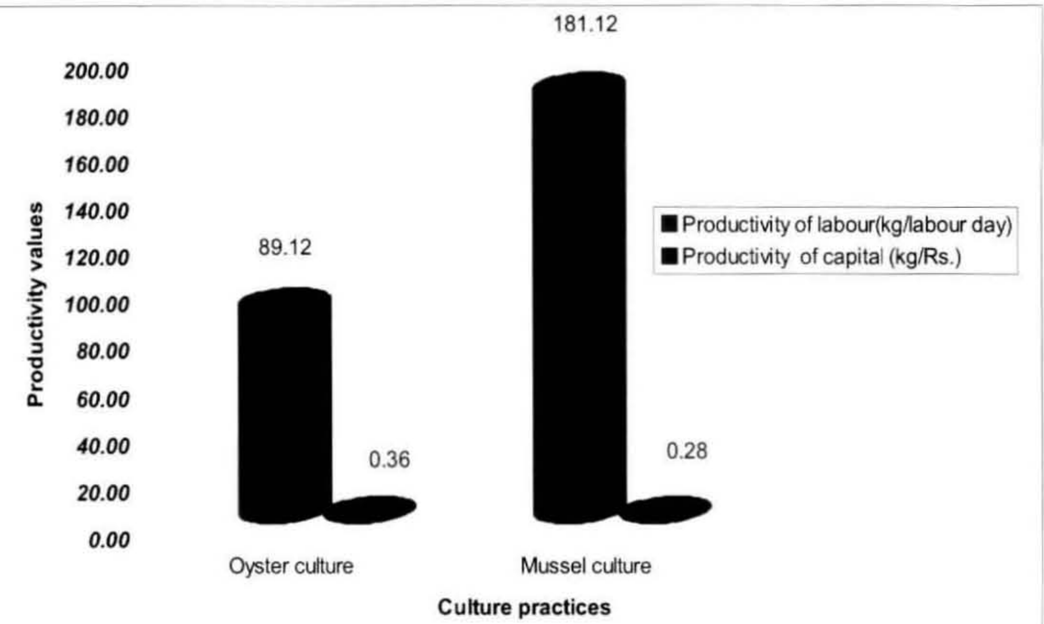


Figure-18. Productivity of labour and capital in oyster and mussel culture

In mussel farming, the labour requirement is less and production is high than edible oyster culture and hence productivity of labour is comparatively high. The lower production costs in edible oyster farming explain the higher productivity of capital.

A comparison of the labour cost/ kg of produce in oyster and mussel culture is given in Figure-19.

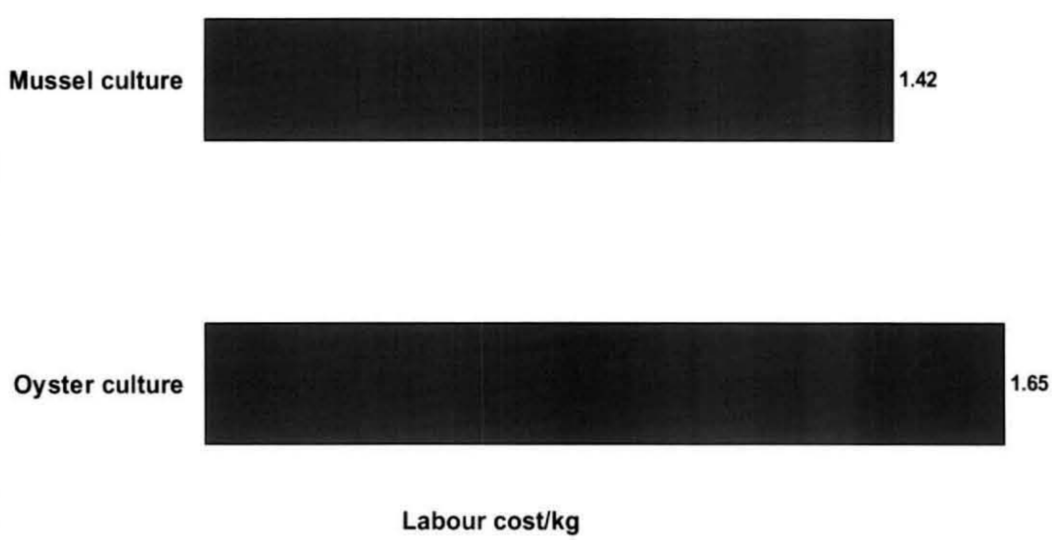


Figure-19. A comparison of labour cost/kg in mussel and oyster culture

The labour requirement and labour cost incurred are higher in oyster culture than for mussel. Oyster culture requires shell drilling and cleaning before laying the cultch material for spat settlement which requires more labour. Shucking the meat from the shell after harvest also requires labour, which is not required in mussel culture, making it less labour intensive.

DISCUSSION

5. DISCUSSION

5.1. Externalities

Industrial development brings unintended benefits or losses to the society. Development of industries provides employment opportunities to the local people. It brings about socio-economic improvement in the area, uplifting the living standards of the people. The land value in the area will increase. These all are positive aspects. On the other hand, industrial development will bring with itself, problems like pollution, reclamation of lands, water abstraction which all negatively affects the environment. Coastal aquaculture generates positive impacts like increase in land value, higher productivity and profitability, better household income, infrastructure development in the coastal belt, improvement in the living standards and socio-economic status as well as negative externalities like mangrove destruction, salinisation of land and water, conversion of agricultural land, reclamation and pollution. Coastal aquaculture also suffers from negative externalities like pollution caused by industrial effluents, sewage and domestic wastes.

5.1.1. Externalities affecting coastal aquaculture

5.1.1.1. Pollution

In any economic analysis there are two basic requirements that should be recognised for the acceptance of pollution problem to exist. Firstly the activity must have some physical impact on the environment. Secondly that physical impact must induce some negative human reaction (Soley *et al.*, 1994). In the present study, the discharge of effluents from peeling sheds and processing plants in the Ezhupunna region has affected the quality of water available for aquaculture. The water analysis of six farms each receiving water from five of the canals during the three months (May-July, 2003) showed that more than 70% of the farms received moderately to highly polluted water for shrimp culture.

The Kerala State Pollution Control Board (KSPCB), responsible for pollution control and maintaining quality of inland and tidal waterways of Kerala has set standards for waters in marine coastal areas. The maximum tolerance limit for BOD and COD was set at 100 and 250 mg/l, respectively. The prescribed ideal water quality parameters for aquaculture in brackish and marine waters were suggested by Anon (1997). BOD was not to exceed 15 mg/l, COD 70 mg/l and total ammonia 0.1 mg/l. In the present study, it was seen that the water quality parameters exceeded the maximum tolerance limit. Central Pollution Control Board (CPCB) has set effluent standard for sea food industry and raw meat processing unit (Goel and Sharma, 1996). The absence of proper controlling and monitoring mechanisms is the root cause of pollution.

The intensity of pollution is further evident in low productivity of farms which received polluted waters (597kg/ha) compared to farms which were not much affected by pollution (951kg/ha) in the present study. The average production of improved perennial farms affected by pollution in Ezhupunna area was more than those affected by disease in Ernakulam and Alappuzha districts. The farms in Ezhupunna region not affected by pollution showed better production than even the non affected farms in Ernakulam and Alappuzha districts, indicating the potential in the Ezhupunna area if pollution could be kept at minimum.

Sekar (2001) has discussed the decrease in productivity of different agricultural crops and decrease in the cropped area over years due to common property resource degradation in Coimbatore. A reduction to the tune of 37% in shrimp production per hectare is observed in this study due to pollution. Based on the present study, a revenue loss of about US$ 6.52 million (about Rs. 300 million) was worked out from shrimp farming alone in Ernakulam district, assuming 37% reduction in at least 25% of the 11,213 ha under shrimp culture by pollution.

Sekar (2001) has worked out the total averting expenditure to Rs. 545/ ha for common property resource degradation in Coimbatore. The annual average aver-def expenditure incurred in the present study for shrimp farming was Rs 615.55 / acre for neem oil cake, bleaching powder, potassium per manganate, etc.

Amarnath and Krishnamoorthy (2001) reported reduction in land productivity and land value due to tannery pollution in Vellore, Tamil Nadu. A reduction in the lease amount of the farm land to the tune of Rs. 7500/ acre from 1995 to 2003 (from an average of Rs.19, 000/ acre in 1995 to Rs.11,500 /acre in 2003) is observed in the current study in Ezhupunna area. The trend of owners giving away their land for lease was the most conspicuous feature seen in the study area.

A shift in cropping pattern to more tolerant varieties was reported due to tannery pollution in Vellore, Tamil Nadu (Amarnath and Krishnamoorthy, 2001). In the present study also, a trend of shifting of species to less capital intensive Indian white shrimp was seen, to avoid the higher risk and uncertainity.

The study used CV method to measure the willingness of the people to pay for good quality water for shrimp culture. Deshmukh (2003) employed CV method for analysing the pollution in Pachganga river by domestic waste water and found that more than 90% of the respondents were WTP for improved water quality. Whitehead and Groothuis (1992) applied CV method to measure the economic benefits of best management practices used to reduce agricultural non point pollution in Eastern North Carolina.

The people will be willing to pay for an environmental good or service only if they are convinced of the benefits arising out of it. The farmers with better perception of pollution problem are aware of the benefits like increased yield and revenue, once they avail good quality water for aquaculture. Similarly farmers with more land area and high pollution load will be willing to pay more towards good quality water as is evident in the results of the present study.

Hedonic method was employed by Sekar (2001) to study the externality of common property resource degradation in Muthupalayam village in Coimbatore. In this study also, hedonic model was used for determining the decline in the aquaculture land value owing to pollution. The value of aquaculture land is determined by many aspects like the production and profit from the area during the previous years, the availability of good quality water for farming, water intake facility, water exchange facility, price of shrimp in the international market etc. The study by Sekar (2001) showed the variable water quality index significant at 1% level in determining the value of the crop land. In the present study also, water quality index was significant at 1%level in determining the aquaculture land value. The farms located towards the tail end of the canal are receiving more polluted waters because of poor flushing and such areas fetch low land value. Periodic deepening and widening of the canals and water ways could facilitate the flushing of the pollutants present in the system to a certain extent. Construction of bunds and other structures blocking the natural flow of water should be avoided.

The canal from which water was taken for farming was found to affect the land value significantly. "*Alumthodu*" which had relatively less number of polluting bodies in the vicinity, fetched maximum land value. The average land value of the farms with water flow from Alumthodu was Rs. 2.11 lakh/acre. Farmers drawing water from Penadumuttu canal which had maximum pollution in the vicinity fetched the lowest price of Rs.1.0 lakhs/acre.

There was a proposal for setting up an effluent treatment plant in Chandiroor area (nearby the present study site), for treating the solid wastes and effluents from the peeling sheds in the vicinity (The Hindu, 16th February, 2000) and until now, nothing has materialised. The Korean government was willing to spend 4 trillion won (Rs.162 million) for sewage treatment plant to control harmful algal blooming, although the economic loss due to blooming was only 79 billion won (Rs. 3 million) per annum in 1995. The government correctly regarded it as a social overhead capital which cannot be converted into direct economic benefit (Lee and Chah, 1996). Top priority should be accorded to establish treatment plants considering the immediate social benefits which will definitely help to attain higher returns and thereby economic surplus in the long run. Jani (2003) assessed the costs of establishing common effluent treatment plants for reducing the pollution load in Gujarat industrial development corporation as 20 to 22 % of the total production costs. Considering the employment generated by the units and the very high value additions, it was prudent to go for effective pollution control measures rather than closing down the units. Hence it is not enough that the polluting firms have treatment plants in their premises, it is equally important to ensure their proper operation and maintenance. Dumping of effluents in monsoon and night times should be prevented. Stringent regulations should be formulated and implemented in each locality by the local bodies like Panchayats to prevent further degradation.

The Vembanad backwater system, was reported to suffer an ecological disaster due to the large scale pollution of its waters, indiscriminate exploitation of its resources and human intervention in the form of reclamation of land and other encroachments. While the lake has shrunk to 37 per cent of its original area because of human intervention, the pollution levels have increased several-fold. The

Kochi city alone emptied 2,550 million litres of urban sewage into the lake daily. About 260 million litres of trade effluents reach Periyar estuary, a part of the lake system, every day from the industrial belt of Kochi. The water is highly acidic there and loaded with ammonia, fluorides and phosphates (The Hindu, 4 th February, 2004). The retting of coconut husk in the lake, the release of chemicals by the coir industry, dumping of wastes from houseboats and other service boats into the lake had polluted the water. As the shutters of the Thanneermukkom barriage had been closed, there was no flow of water in the area which worsened the situation. The flow of fresh water into the lake through the River Pampa has also decreased which has further worsened the situation.

CPCB has asked all the polluting industrial units in Periyar river belt either to establish treatment plant in their premises or to shut down the units following the Supreme Court order in order to contain the pollution problem.

The fish fauna and reptile wealth and molluscs found in the lake are facing a threat to their existence. Periodic outbreak of fish disease was common in Kuttanad region of Vembanad lake. Large-scale pollution of Vembanad lake from the effluents discharged from big industrial houses have resulted in mass mortality of fishes (The Hindu, 4 th February, 2004). The economic loss resulting from fish death on one occasion during 2003-04 alone was estimated to be of about Rupees one crore.

Ashtamudi lake, the second largest wetland in Kerala and deepest among all the estuaries of Kerala suffers pollution from oil spills from thousands of fishing boats, industries such as paper mills, aluminum industries, ceramics and from coconut husk retting (WWF, 2003). The Panfish book compiled and published by the Kerala State Fisheries Department cited that different industrial units like The Indian Rare Earths, Chavara, The Kerala Minerals and Metals Ltd. Chavara, The Kerala Ceramics Ltd. Kundara and KEL, Kundara were polluting the water bodies (Anon, 2002b). Disposal of huge quantities of untreated sewage from Kollam city, direct disposal of human excreta from hanging latrines all added to the pollution in the lake. Natural habitat faces serious degradation including reclamation of the estuary (WWF, 2003).

In economic analysis pollution exist as a negative externality of production/consumption. Some of the costs of private production/consumption decision fall outside of the parties making such decisions. So while the decisions taken may be rational and efficient for the private parties making decisions, from the point of view of the society, they may be neither rational nor efficient (Soley *et al.*, 1994). So pollution occurs because the economic system fails to alert firms to the true environmental cost of their activities (Garrod and Whitmarsh, 1995). The pollution sufferers who suffer loss of income due to the externality will find it interesting to take corrective action only if he expects that transaction costs are inferior to the value of damage suffered (Wijkstrom, 1995).

In principle, the externality problem could be overcome if it were possible for private individuals to reach some level of bargain whereby the polluter and pollution sufferer compensate each other. The bargain could conceivably involve the pollution sufferer paying the polluter to reduce the amount of pollution he emits and the polluter compensating the pollution sufferer for the marginal pollution damage he has caused (Garrod and Whitmarsh, 1995). This is the basis of "Coase Theorem" which argues that who pays whom will depend on ownership of the property rights to the environmental resource that is being polluted and whoever is therefore liable for any damage that is done to it (Coase, 1960).

A major property right is the right of the people to sue for the damage done to them by others (Lee and Chah, 1996). Since property rights to marine environment are badly defined and the number of individuals involved is large, the task of identifying the potential sufferers from pollution and firms responsible for pollution and quantifying their share of pollution is difficult which is a pre-requisite for Coasean theorem (Garrod and Whitmarsh, 1995). Secondly the free-rider problem may prevent the compensation system from functioning properly.

Since the market mechanism sends out wrong signals to firms by allowing them to disregard pollution cost and where the polluter and pollution sufferer are unable to remedy this market failure by striking a deal over who compensates whom, then government intervention is warranted. The government would start by comparing the value of damage suffered by the sufferer with the value added, generated by those causing pollution. If the damage caused is less than the net value added it will make economic sense for the polluter to compensate those who have been polluted. If the damage caused is greater than the net value added, steps should be taken to cease the productive activity of the polluter (Wijkstrom, 1995).

In the past regulatory control instruments have tended to be adopted which simply set an upper limit on the acceptable level of environmental damage better known as 'command and control' regulation. But regulations can be inefficient because most regulations apply equally to all firms regardless of their individual costs and benefits (Lee and Chah, 1996).

More recently a number of alternative market based instruments are available which in some ways represent a very much superior approach to pollution control (Garrod and Whitmarsh, 1995). Soley *et al.* (1994) have suggested tariff on stocking density or on time-continuous production, to reduce the adverse impact of Scottish salmon farming industry on the coastal environment. Wijkstrom (1995) has discussed user charges or product charges as economic instruments to regulate externalities. User charges are those made for a particular service linked to environmental management. Product charges are linked to the purchase of an environmentally damaging product or service.

A rather different method also based on market incentives is tradeable pollution limits. This system is based on the proposition that if pollution permits could be traded amongst polluters, the overall costs of pollution control could be minimised. The market forces will cause the available pollution permits to gravitate towards those firms finding pollution control expensive leaving those firms able to achieve the required reduction in pollution at least cost to undertake the necessary emission reduction. The added advantage compared to taxes is that the authority does not need to estimate the level of marginal damage cost that would be incurred at the socially optimal level of production since this would be determined by the firms bidding against each other for the right to pollute (Garrod and Whitmarsh, 1995).

Thus it is known that a variety of economic mechanism exists which might be applied in the control of pollution affecting aquaculture. It is necessary to investigate the various options in detail and to compare them with their performance in other industries and in different countries to select the most suitable one. The pollution control mechanism in the state should be further strengthened with adequate powers and infrastructure to implement all the environmental laws and regulations.

5.1.1.2. Disease

White spot virus (WSV) has emerged as the most virulent and lethal virus so far detected not only in the shrimp farms of India but in the whole of Asia. China reported losses to the tune of US$ one billion due to this virus in 1993 and Thailand 500 million $ in 1996 (Jory, 1999). A 7-10% drop in the cultured shrimp production in Asia during 1996 has been attributed to this dreaded virus (Vijayan *et al.*, 2000). During 1999-2000, Ecuador lost one billion $ due to WSV. In Thailand, the virus hit the industry in 1994 and resulted in an economic loss of $1.5 billion through the subsequent five years. For Indonesia, the production stagnated from 1991, when white spot disease attacked the country, resulting in potential production losses of roughly $ one billion through the subsequent ten years. In the past ten years it has been estimated that this viral disease has cost the aquaculture industry as a whole between $ 20-30 billion (Mc Clennen, 2004).

Large scale mortalities in India due to this virus were first noticed during October 1994 causing severe economic losses to the shrimp farmers (Sekhar and Mishra, 1998). Sukumaran *et al.* (1995) has reported the economic loss due to this virus in Vedaranyam taluk of Tamil Nadu to the tune of Rs. 2.42 lakhs/ha/crop. Indian shrimp aquaculture production boomed between 1990 and 1995 when it reached 97, 500 MT, but decreased to 54, 500 MT in 1997, mainly due to a viral disease epidemic, caused by the White Spot Syndrome Virus. This epidemic has been afflicting the country for several years now and has caused an estimated loss of revenue of about US$ 200 million (Rs. 9.6 million) during 1999-2000, affecting national export earnings and shrimp producers of both traditional and extensive farms (FAO, 2004).

The present study done in Ernakulam, Alappuzha and Kollam districts of Kerala has shown an average of 44% (404kg/ha) reduction in production in the improved traditional systems and 47% (718 kg/ha) reduction in the extensive shrimp farming systems due to WSV. In the present study it was observed that WSV affected 25.8% of the improved traditional shrimp farms and 53.2% of the extensive shrimp culture systems (area wise). The revenue loss due to this disease does not end with loss in shrimp production alone. Loss of employment opportunities in aquaculture, processing and marketing sectors are to be taken into account. It was found that while improved traditional farms unaffected by disease made use of 162 labour days, affected farms utilised only 86 labour days. In the extensive system it was 363 and 170 labour days respectively. The revenue loss due to white spot disease in the Indian shrimp farming industry during the last three years is given in Table-29. The total shrimp farm area affected by white spot disease under each shrimp culture system is estimated based on the percentage of disease affected farm area observed in each of these systems in the present study.

Economic loss in employment sector was calculated at the rate of Rs. Rs.150/ labour day, Rs.160/ labour day and Rs. 170/ labour day for 2001-02, 2002-03 and 2003-04 respectively. Approximately, an equal employment loss has occurred in the seafood processing and marketing sectors. So for calculating the revenue loss in the employment sector, labour loss in marketing and processing sector is also included and hence the loss is doubled.

Loss in shrimp production due to white spot disease alone was about 40,000 t in all the three years. Domestic consumption for shrimp is meagre in India. Major chunk of the cultured shrimps are exported. Forex earnings of about US $ 290 million per annum (Rs. 1,400 crore) were lost due to disease alone. Economic loss in employment sector was approximately US $ 70 million (Rs. 336 crores). About 200 lakh labour days of employment were lost because of disease problem. Nearly 1 lakh people could have been employed regularly by the Indian shrimp industry for the 6 months, if disease occurrence was not there.

There has been a reduction in shrimp farming area, both in the traditional and extensive sectors, from 2001-02 to 2003-04. The unit value realisation of frozen shrimp has also come down over these years. The low price realisation for shrimp and the impact of the viral disease has led to this reduction in shrimp farming area. Farmers who incurred huge losses due to the viral disease in previous years were reluctant to do the farming in subsequent years.

Table-29. The economic loss in Indian shrimp farming sector due to white spot viral disease

Year	2001-02	2002-03	2003-04
Total area under traditional / Improved traditional prawn filtration (ha)	61,023	59,949	59,928
Area under traditional / Improved traditional prawn filtration affected by white spot virus (@ 25.8%) (ha)	15,744	15,467	15,461
Production loss @ 404 kg/ha (t)	6,361	6,249	6,246
Labour loss @ 76 labour days/ha (labour days)	11,96,544	11,75,492	11,75,036
Area under extensive culture practice (ha)	96,377	92,131	94,672
Area under extensive culture practice affected by white spot virus (@ 53.2%) (ha)	51,273	49,014	50,366
Production loss @ 718 kg/ha (t)	36,814	35,192	36,163
Labour loss @ 193 labour days/ha (labour days)	98,95,689	94,59,702	97,20,638
Total production loss (t)	43,175	41,441	42,409
Unit value realisation of frozen shrimp ($/kg)	6.82	7.07	6.76
Economic loss in shrimp production sector (Million $)	294	293	287
Total labour loss (lakh labour days)	222	213	218
Economic loss in the total employment sector (Million $)	69	71	77
Total revenue loss (Million $)	363	364	364

Note: 1$=Rs.48

Early detection of virus will help in taking proper management steps to control the incidence of WSV outbreaks. PCR (polymerase chain reaction) based methods are gaining popularity for detection of a number of pathogens affecting man and animals (Karunasagar and Karunasagar, 1997). The non-availability of pathogen free broodstock of tiger shrimp from the wild in sufficient numbers push the hatchery operators into a very desperate situation which forces them to use what ever broodstock they get from fishermen for seed production without being tested for viral infections. Supply of PCR tested seeds to the farmers by the hatchery operators is to be ensured (Sakthivel and Ramamurthy, 2003). Specific pathogen free (SPF) brood stock for tiger shrimp has to be developed.

Mohan and Shankar (1995) have suggested several methods like disinfection of pond bottom and drying until it cracks, disinfection of water from the infected pond before discharging it into the environment, setting up of effluent treatment tank near the outlet and reservoir tank near the inlet, destruction of dead shrimp by burning and declaring crop holiday for 4-5 months to reduce the viral load in the system. A low stocking density has to be maintained in the subsequent crop to reduce the risks of disease onset.

Considering the forex earned by shrimp and the employment opportunities generated, the government should come forward to help the farmers affected by disease. Crop insurance or group insurance scheme for farmers at a comparatively low premium, provision for subsidies on seed, feed can go a long way in helping farmers. Aquaculture cess can be imposed on the shrimp exports which can be utilised by the government for farmers' welfare in case of crop failure or economic loss. Government should come forward to implement the Coastal Zone Management Plan (CZMP) in an efficient way.

WSV obviously had a negative impact on the short term sustainability of the shrimp farming industry world wide. Following WSV outbreak, many countries have completely banned mangrove destruction, reduced the stocking density in shrimp farms to conserve the marine environment in a sustainable way. They were forced to count their losses, fully evaluate what were once considered to be unfortunate but unaccountable externalities and began to practice a more environmentally sustainable business.

The need for diversification of aquaculture has become imperative to sustain the growth in India's marine exports. The diversification is not only significant for augmenting our exports but also for carving new nitches and even capturing new markets, besides directly reflecting on rural economic development.

5.1.2. Externalities generated by coastal aquaculture

5.1.2.1. Mangrove destruction

Mangrove habitats have been removed and the land has been reclaimed for several purposes like agriculture, harbour development, salt industries, cattle grazing, fuel wood use, residential purpose, industrial development including aquaculture. The total mangrove area in India reported by various workers over the years were 6,740 km^2 (MoEF, 1987), 4,256 km^2 (MoEF, 1994), 4,533 km^2 (FSI, 1995), 4,827 km^2 (FSI, 1997) and 4,871 km^2 (FSI, 1999). It is quite clear that mangrove destruction has taken place mostly between 1987 and 1994. The satellite imagery pictures from Krishna and Guntur districts of Andhra Pradesh have shown mangrove destruction for shrimp farm construction (Alagarswami, 1995). National Remote Sensing Agency has recorded a decline of 70,000 ha of mangroves within the six year period from 1975 to 1981 (Kathiresan, 1997). Krishnamoorthy and Ramachandran (2000) observed that except for the mangroves in Andaman and Nicobar Islands and Gujarat all are highly degraded and aquaculture has been reported as one of the reasons. The extent of conversion of mangroves for aquaculture has not been estimated. Rao and Ravichandran (2001) have reported a 30% reduction in mangrove area in India between 1987 and 1997 with maximum reductions in West Bengal and Kerala. In Gujarat, 253 km^2 of mangroves disappeared after the cyclone. In 1998 the mangrove area in the state was 648 km^2, whereas it got reduced to 395 km^2 in 1999 (The Hindu, 11th June, 2000). Rout and Das (2003) reported that in India about 40 million ha of mangrove areas have been converted for other uses.

Basha (1992) reported 17km^2 of mangrove area in Kerala and at present the mangrove area has increased to 19.24km^2 (Anon, 2002b). A conservative estimate indicated that the total extent of mangrove areas in the Cochin backwaters and Vembanad lake was around 70,000ha (Blasco *et al.*, 1975). This area got reduced progressively as mangrove areas were converted for various purposes like coconut plantations, traditional shrimp culture, reclamation and other development activities. A total mangrove area of 455 ha has been reported in and around Vembanad estuary (Anon, 2002b). A survey by ADB / NACA (1998) showed that about 5% of the shrimp farms in India have been constructed on former mangrove areas. In the present study, 21% of the farmers (of a total of 135 farmers) indeed agreed that they have destroyed mangroves one way or other for aquaculture purpose.

Wetlands and mangrove swamps have been filled up in the recent past for housing projects such as Girinagar, Panampilly Nagar, Jawahar Nagar, Kumaranasan Nagar etc in Cochin City. The construction of Cochin bye pass from Edapally to Kumabalam has wiped out many pockets of mangrove swamps (Subramanian, 2000). The mangrove area in Chilavannur and Thevara water front area has been eroded to one tenth of its earlier size. The population explosion, increased human activities and unprecedented rate of urbanisation are stated to be the reasons. There are reports of mangrove destruction in Kannur and Kasargod districts. In Kannur district itself, nearly 150 ha of mangroves were destroyed for setting up aqua farms (The Hindu, 27th May, 2002). However the exact area of mangrove destruction in Kerala as a whole for shrimp farming is not available.

The goods and services offered by mangrove ecosystem are well studied and documented. The mangroves protect the shoreline from sea erosion, they provide food, habitat and nursery ground for fishes, shrimps, help in nutrient cycling, provides wood, charcoal and are extremely productive sources of fishes, shrimps, molluscs and crabs. The belief that mangroves and other wetlands were waste lands gave the impetus for their conversion to other more profitable uses (Hamilton *et al.*, 1989). Primavera (1993, 1997) has reviewed values placed on mangrove systems and their products and services by many authors. Many of the previous valuations for complete unmanaged mangroves ranging from US$ 500-1550/ha/year may be gross under estimations. Usually mangrove valuation efforts cover only marketed items. Other benefits are not included because of their subsistence level of use or of problems in assigning monetary values. A comprehensive economic analysis to determine the true cost of losing mangrove ecosystem has been developed by Hamilton *et al.* (1989).

Cost benefit analysis by Ruitenbeek (1994) for Bintuni Bay mangroves, Indonesia incorporated values for non market functions like subsistence use, erosion control and filtering services. The economics of complete goods and services of mangroves studied by Chamberlain (1991) place mangroves on par with intensive shrimp culture. The cost benefit analysis of mangroves in Fiji by Lal (1990) showed that mangroves are not wastelands to be reclaimed. The NPV for alternative uses of mangroves was negative. An economic study by Pongthanapanich (1996) worked out the opportunity costs of converting mangroves into shrimp farming. The expenditures incurred by the shrimp farmers in building water treatment ponds were also calculated. Comparative economics of land use options in mangroves was studied by Hambrey (1996). Traditional extensive shrimp farming failed to offer any returns on investment and had high payback period. The returns per unit area were negative for tambaks (extensive culture ponds in Indonesia where shrimp and fish are grown).

Mangrove afforestation programmes started recently all over the world as problems in destruction of mangroves were understood. Peru, Ecuador, Mexico have all started mangrove afforestation programmes in the shrimp ponds abandoned due to disease so that they could be restored to their former status (Mc Clennen, 2004). In India, subsequent to the setting up of National mangrove committee in 1987, afforestation trials were done in Goa, in Maharashtra near Ratnagiri and Kalbadvi estuary and also in Sunderbans. Aerial seeding of mangroves on the mudflats of Sunderbans tried in 1989 achieved 50% success. The afforestation programme for mangrove conservation was implemented with the financial assistance of Ministry of Environment and Forests. The Centre for Research on Sustainable Agriculture and Rural Development of M. S. Swaminathan Research Foundation, Chennai initiated a project and identified four sites for conservation of mangrove genetic resources. Mangrove ecosystem information centre has been established under this centre and also under Centre of Advanced Studies in Marine Biology to ensure rational utilisation of these resources on a sustainable basis (Rout and Das, 2003). There are reports of mangrove restoration programmes even in Kerala. The Kattukandum mangroves of Ayiramthengu near Kollam were given a fresh life by the concerted efforts of the State Fisheries Department.

The extent of mangrove conversion for aquaculture is still to be documented properly. Remote sensing and Geographic Information System (GIS) for assessing and monitoring the health of mangrove ecosystem are very essential for formulating appropriate management strategies for their conservation (Devaraj *et al.*, 1999a).

Legal provisions preventing the environmental impacts related to the removal of mangroves for shrimp pond culture were derived from various acts, particularly The Wild Life (Protection) Act, 1972; The Water (Prevention and Control of Pollution) Act, 1974 and subsequent amendments to the act, The Environment (Protection) Act, 1986 and the rules, amendments and notifications subsequently issued thereafter and more specifically the CRZ notification (Alagarswami, 1995). Fifteen mangrove areas have been identified for intensive conservation and management purposes. The mangroves of the Sunderbans in West Bengal have been declared as biosphere reserves, where zonation has been carried out permitting or restricting certain activities. The mangroves of Pichavaram forests in Tamil Nadu are protected. All the mudflats, marshy surroundings and mangrove ecosystem have been classified under CRZ as CRZ-I.

The Ministry of Environment and Forests, Government of India insists upon the imperative need to undertake detailed EIA of large scale aquaculture projects. EIA should include physical and biological resources, hydrology and water quality, socio economic aspects, human use values and legal aspects (Alagarswami, 1995). Under CZMP, Government of Kerala, a buffer zone of 50 m distance belt around the mangroves will be maintained even if the width of the creek, back water and river is less than 50 m (Devaraj *et al.*, 1999a). All these ensure that mangrove areas will not be touched for other purposes.

Apart from protecting the existing mangroves, afforestation programmes are to be undertaken in areas were mangrove destruction took place. In many areas in Vypeen Island, especially Malippuram, Valappu, Murikkumpadom and many residential areas in Cochin Corporation like Thevara, Panampilly nagar, Girinagar, Maradu, where mangroves were destroyed for housing, developmental activities, agriculture and shrimp culture, mangroves can be planted at least on a small scale with the participation of local people. In many of the areas mangroves were destroyed considering as wastelands without knowing its importance and implications. Several studies (Chamberlain, 1991; Lal, 1990; Hambrey, 1996) clearly show that the benefits arising from them are having multi-dimensional impact on society. Awareness should be created among the mangrove-using people for conserving this resource to a greater extent. Suitable utilisation of the professional skills and experience of the ecologists for natural resource management should be encouraged in this endeavour. R and D efforts need to be strengthened to provide all information about the widespread economic and ecological impacts of mangroves to policy makers and mangrove zone managers to evolve suitable policy measures.

5.1.2.2. Land conversion and leasing policies

The Indian Fisheries Act, 1893 give powers to the State Government to enact state acts and make rules and regulations for fisheries management. A number of maritime states passed marine fishing regulation acts/rules in 1980s. Although they were primarily concerned with regulating fishing in public as well as private waters through a system of licensing by government authorities, they are also concerned with resources and ecology. The Goa Fish Farming Regulation Act, 1991 is specific to brackish water aquaculture. Exclusive concern for the environment as a whole became legalised with The Wild Life Act, 1972, The Water Act, 1974, The Air (Prevention and Control Of Pollution) Act, 1981, The Environment Act, 1986 and CRZ Notification 1991 (Alagarswami, 1995).

Gopalan *et al.* (1983) has reported that 5,900 ha of the Vembanad estuary have been reclaimed for paddy cum shrimp culture until 1984. About 61 km^2 of *Kari* land have been converted for agriculture in the southern region namely Kuttanad. An equal area has been converted for paddy cum prawn culture in the middle and northern sectors (Vypeen, Narakkal, Edavanakad, Cherai and Parur) of the Cochin estuary (Subrahmanian, 2000). There has been a sizable reduction in the wet lands along North Kerala coast covering an area of about 540 km^2 in the past three decades (Nandakumar and Salim, 1997).

Many of the *pokkali* lands have been reclaimed for several developmental purposes like residential projects, industrial purposes etc over the years. The land value has increased manifold over the years. Public are aware of the demerits of such large scale conversions and have begun to protest against such conversions.

Most of the land beyond the mangrove zone in coastal belt is classified as agricultural land in the records of State Revenue Department. The record finds no mention of lands under aquaculture category. Most of these lands being sandy in nature are unfit for agriculture and do not warrant classification under the category of agriculture lands. So when aquaculture is done here they have been taken as constructed on agriculture land. So it is necessary to reclassify these lands in revenue records.

Each state government has a land use policy which is implemented by a single authority like Department of Environment or Land Use Board. The land use policy of the Government of Kerala does not permit conversion of seasonal fields permanently for shrimp farming. During monsoon period, paddy cultivation has to be carried out in these fields. In spite of these, in areas where sufficient saline water is available in monsoon season, like in Chellanam, Kannamaly, people are growing shrimp. Intrusion of saline water was found to spoil the *pokkali* cultivation resulting in economic loss in these areas. So the consistently low paddy production lead to a situation where the fields are either lying idle or are utilised for growing shrimp even in monsoon season.

Instead of growing shrimp or lying idle, polyculture system with multispecies combination with herbivorous fishes like grey mullet, mullets, milkfish, pearl spot and tilapia which are environmental friendly and which require fewer inputs can be tried here profitably. If such practices are extended in a phased manner to unutilised paddy field ecosystems, enormous quantity of fish can be produced (Purushan, 2003). In the current investigation, a production of 5.6 t / ha/crop was observed from polyculture system of fishes alone. Sathiadhas *et al.* (2003) reported a maximum yield of 7.2 t /ha from polyculture system of fishes in Vypeen Island. If proper management techniques are adopted, average fish production of 2.5 t/ha/crop could be obtained from *pokkali* fields (Purushan, 2003). If polyculture of grey mullet, milkfish, mullets is attempted in at least 10 % of the 12,873 ha of *pokkali* lands in Kerala, which is mostly remaining idle during the paddy growing season, a minimum of 3,218 t of fish can be produced easily earning a total income of Rs. 257 million. This would generate employment of about 19 lakh labour-days. In simpler forms this would provide regular employment for 10,600 people for 6 months.

The leasing system followed in traditional shrimp farming system is governed by the Travancore-Cochin Fisheries Act, 1950. Under this act a set of rules to regulate traditional shrimp farming known as Regulation of Fishing in Private Water Rules, 1974 was brought in by the Government of Kerala. The licensing system for traditional farming was thus introduced (CIBA, 2002). Forceful harvesting in traditional shrimp farms by April 14^{th} by Fishermen Union does not ensure proper growth of shrimp. If the produce is not harvested by April 14^{th}, the local fisher folk harvest the shrimp themselves and legal protection for the farmer cannot be ensured for this leasing system beyond that date. Fisheries in the erstwhile Malabar area is still governed by the Indian Fisheries (Madras Amendment) Act, 1927. The need for a uniform fisheries act or aquaculture regulation act is over due.

The land use policy of Kerala government should be suitably amended to extend the leasing period of traditional prawn filtration up to May 14^{th}. This would ensure sufficient growth for shrimp seeds entering the field during March. The shrimp seeds which enter the field during the month of March will be harvested as small size groups fetching minimal price. When 1 kg of 60 count *P.monodon* fetches Rs. 190, the same quantity of 90 count fetches only Rs.100. When *P.indicus* of grade 170 count fetches Rs. 100-120/kg, meat count (above 400 count) fetches only Rs.50-80. The *P.indicus* seeds which entered the field in March will be harvested as meat count only. But if the leasing period is extended up to May 14^{th}, they could grow at least to 170 count level fetching a higher price. In the same way, *P.monodon* seeds entering the field in March currently reach a maximum of 90 count level only by April which is having the potential to grow up to 60 count level by mid May. The present leasing period from mid November to mid April was fixed a long time ago, when natural desalinisation was the only way for traditional paddy cultivation. With the advancements in agriculture sector, the fields can be made ready for paddy cultivation within a short period in June itself by the use of pumps (CIBA, 2002). There should be provision for legal protection of the crop during the leasing period from poachers and encroachers. The land use policy should be modified to allow environment friendly low cost fish polyculture practices during monsoon season in the unutilised paddy field ecosystems rather than allowing them to remain idle. Reclassification of lands put under agricultural category in the Revenue records into agriculture and aquaculture category as per their suitability is a prerequisite for this.

Strict vigil is to be observed to prevent *pokkali* land reclamation for other developmental purposes.

5.1.2.3. Salinisation of land and water

Traditional aquaculture systems in Kerala are located in low-lying natural inter tidal zone generally inundated with saline water during spring tide. So salinisation problem do not arise due to the development of any artificial system. The drinking water problems in the coastal areas of Kerala, especially in the Vypeen Island cannot be neglected as a whole. Landward spreading of salinisation due to shrimp farming arises when culture is attempted in areas away from coastal belt. Extensive systems adopted in elevated areas close to agricultural fields attract such complaints (Rao and Ravichandran, 2001). The practice of doing shrimp culture towards the landward side away from coastal belt by taking saline water into the ponds through channels or canals or pipes should be strictly prohibited. Careful identification of aquaculture zones and provision of buffer zones against possible impact on other land users can take care of salinisation problems (Alagarswami, 1995). In areas where land has turned saline, saline resistant crops like coconut, vegetables like pea, ladies finger, bitter gourd, cucumber, ash gourd, yellow pumpkin, amaranthus etc can be grown. Eco friendly integrated aquaculture practices with pig or poultry which give fairly high returns with minimum inputs can be attempted. Pig or poultry can be reared on the pond dykes. Fishes like milkfish, mullets, tilapia, pearl spot etc can be grown in ponds. These practices increase the production from unit area since output of one becomes input of another. Sathiadhas *et al.* (2003) reported fish yield of 8.2 t/ ha from integrated farming system of fish and poultry. Also 14,400 eggs could be raised per ha per annum earning a net profit of Rs. 5.5 lakh/ha from the integrated farming system. The production and profit mentioned above was worked out based on small farms of 10-20 cents. However the picture may not be the same for large farms. The integrated farming could be profitably taken up as a family enterprise on a small scale.

Ever since shrimp farming transformed from traditional to extensive activity several allegations were raised against it. Several Non-Governmental Organisations (NGO) teamed up with coastal communities demanding a total ban on shrimp farms in coastal states like Andhra Pradesh and Tamil Nadu. The research institutions have taken the stand that the allegations about the shrimp farms are mostly exaggerated and even if partly correct, they could be rectified by adopting proper scientific methods of farming. The major problems in shrimp farming were essentially due to the unregulated growth of the farms. Scientific remedies and methods are available for refining the current practices to make them socially and environmentally acceptable. Evolving appropriate policies and development of sustainable shrimp farms in India is handicapped by the non-availability of the quantitative and qualitative scientific data on the factors responsible for the degradation of the environment. While in individual farms much can be recovered by improved management of systems and in the collective development of the ecosystem, the development shall be restricted to an overall plan on the density of farms and their distribution based on EIA studies. Proper assessment of the carrying capacity of different coastal ecosystems along the Indian coast should be done (Sakthivel, 2001).

5.2. Comparative Economics of Aquaculture Practices

5.2.1. Economics of shrimp culture practices

Menon (1954) reported an yield of 1079 kg/ha from the traditional prawn filtration ponds and Gopinath (1956) had observed 1184 kg/ha. George *et* al. (1968) indicated a production of 514 kg/ha. The expense, revenue, profit and shrimp yield from traditional shrimp filtration from different regions over the years is given in Table-30.

A regressive trend in the yields of shrimps from the traditionally operated paddy fields has been observed from 1950s to late 1970s. The increase in the intensity of exploitation of natural stock and environmental degradation would be the probable reasons. Gopalan *et al.* (1978) obtained higher yields from improved operations in traditional fields from Cherai and Narakkal, *i.e.* by restocking undersized juveniles of *P.monodon* and *P.indicus* caught from the nets back into the fields. The percentage composition of *P.indicus* in the total shrimp yield was 57.55%, which was much higher than in the traditional filtration systems, indicating the effect of selective stocking.

Table-30. Comparative yield and earnings from traditional prawn filtration fields (1974-2002)

Year	Region	Shrimp yield /ha	Total cost /ha	Revenue / ha	Net profit /ha	Shrimp price / kg*	Source
Traditional prawn filtration depending on natural seed alone							
1974	Vypeen	903	2,064	2,996	932	3.44	George, 1974
1978	Vypeen	735	6,238	6,889	651	9.38	George, 1978
1978	Narakkal	638	8,074	6,665	-1,409	8.42	Gopalan et al., 1978
Traditional prawn filtration with selective stocking							
1978	Cherai	965	6,498	8,863	2,365	8.95	Gopalan et al., 1978
1978	Narakkal	815	7,761	8,990	1,229	9.58	Gopalan et al., 1978
1989	Vypeen	623	5,587	7,667	2,080	11.87	Sathiadhas et al.,1989
1992	Edavanakad	739	17,310	21,841	4,531	29.57	Nasser and Noble, 1992
2002	Nayarambalam	931	46,746	81,309	34,563	91.4	Present study
1989	Parur	408	4,353	5,181	828	11.96	Sathiadhas et al.,1989
2002	Parur	1,085	75,598	1,02,000	26,401	101.63	Present study

*Shrimp price/kg was calculated by dividing revenue from shrimp yield alone from a one ha farm by the total shrimp yield per ha. Many of the traditional systems harvested brackishwater fishes also along with shrimps. The revenue from their sale was excluded for this calculation.

The traditional system had several shortcomings like indiscriminate stocking, presence of predators and undesirable species, lack of control over the environmental factors, inadequate growing period, predominance of low valued shrimp species like *M. dobsoni* in the catch etc. (George, 1978) and hence people resorted to improved traditional practices like selective stocking with fast growing species like *P.monodon* and *P.indicus.*

Although more and more farmers resorted to selective stocking from late 1980s, the effect was not shown in the total shrimp production (Sathiadhas *et al.*, 1989; Nasser and Noble, 1992) but was reflected in the percentage contribution of *P.indicus* to the total shrimp yield. The percentage contribution of *P.indicus* to the total shrimp catch was (27%) in the study by Sathiadhas *et al.* (1989) and 25%in the study undertaken by Nasser and Noble (1992) and 22% in the present study. Sathiadhas *et al.* (1989) stated frequent harvesting followed in the traditional fields as the reason for the low shrimp production in spite of selective stocking.

In Vypeen area, the species composition of *P.indicus*, *P.monodon* and *thelly* (*M.dobsoni)* was 28%, 0.8% and 63% (Sathiadhas *et al.*, 1989) and in the present study it was 36%, 7% and 57% respectively. In the study by Sathiadhas *et al.* (1989) in Parur region, the percentage contribution of P.indicus to the total shrimp yield was 29%, *P.monodon* 0.5% and that of *thelly* (*M.dobsoni)* was 65%. In the present study in Parur region it was 26%, 10% and 64% respectively. The effect of selective stocking *P.monodon* and P.indicus is reflected in the species composition in the present study.

In the study by Jayagopal and Sathiadhas (1993) in Ernakulam district, 60% of the farms surveyed stocked seeds of *P.indicus*. The average production in the farms which stocked seeds was 1,163 kg/ha whereas the farms which depended on natural seeds alone reported a production of 952 kg. The percentage contribution of *P.indicus* to the total shrimp catch was 29% whereas it was only 14% in the farms which depended on natural seed alone. An average production of 1,509 kg/ha was reported when data was collected from 195 ha of prawn filtration fields in Ernakulam district. In the present study, all the farmers stocked their ponds either with *P.monodon* or *P.indicus* or both and the effect is shown by the percentage contribution of *P.monodon* (13%) and *P.indicus* (20%) to the total shrimp yield. The study conducted by Jayagopal and Sathiadhas (1993) and the present study showed the effect of selective stocking in the total shrimp yields as well as in the percentage composition of *P.indicus* and *P.monodon*.Jayagopal and Sathiadhas (1993) have reported production of 1,232.5 kg/ha and 1,155 kg/ha from seasonal ponds in Narakkal and Kadamakkudy regions respectively. The present study indicated lower production values of 949 kg/ha and 1,085 kg/ha from Nayarambalam and Parur regions respectively. Although production reported in the present study was lower, higher profits were realised than in the study by Jayagopal and Sathiadhas (1993). The unit price of shrimp was nine times higher in the present study than in the study by Jayagopal and Sathiadhas (1993). This was mainly due to the fact that, compared to 60% of the farmers stocking additionally with *P. indicus* in the study by Jayagopal and Sathiadhas (1993), in the present study, more than 95% of the farmers were stocking *P. monodon* which fetched very high price compared to *P.indicus*.

In the study conducted by George (1974), the shrimp production was 811.55kg /ha from perennial fields. Nasser and Noble (1992) reported shrimp production of 695.7kg/ha. In the present study an average shrimp yield of 747.37 kg/ha/year was obtained from perennial ponds. In spite of selective stocking there was a decline in yield. *Metapenaeus dobsoni* which constituted 60%of the shrimp production (George, 1974) in 1974, contributed only to 34.74% in 1992 (Nasser and Noble, 1992) and 31% in the present study. The decline in *thelly* catches is reflected in the total shrimp yields. The environmental degradation and the increasing exploitation of *thelly* seeds by the Chinese dip nets, stake nets would be the probable reasons.

Although the shrimp production from perennial fields has declined over the years, net profit and the price realised per kg of shrimp have increased over the years. There was an increase in the percentage composition of *P.indicus* and *P.monodon* over the years. The percentage composition of *P.indicus* increased from 34.8% (George, 1974) to 47.31% (Present study, 2004). The percentage composition of *P.monodon* increased from 1.11% (George, 1974) to 21.35% in the same period.

The average yield obtained from seasonal fields was higher than the perennial fields in the present study. This is confirmed by the findings of George (1974), Nasser and Noble (1992) and Jayagopal and Sathiadhas (1993). The higher yields from seasonal fields may be attributed to the higher productivity of the fields. The paddy stumps help to increase the organic production in the field and offer better biological environment to the juvenile shrimps (George, 1974).

In the traditional prawn filtration (seasonal) system, the percentage contribution of land lease to the total cost was 80% (Sathiadhas *et al.*, 1989), 72% (Nasser and Noble, 1992) and 55% in the present study. Labour contributed to 10% of the total cost (Sathiadhas *et al.*, 1989), 11% (Nasser and Noble, 1992) and 22% in the present study. In the perennial prawn fields, land lease contributed to 54%of the total cost (Nasser and Noble, 1992) and 47% in the present study. Labour constituted 21.5% of the total cost (Nasser and Noble, 1992) and 25% in the present study. Compared to late 1980s and early 1990s, the number of farmers resorting to selective stocking and feeding has increased tremendously leading to increased labour requirement.

The average production from scientific shrimp farming in Kerala reported by Kumar and Panikkar (1993) was 820.65 kg/ha. An average yield of 811 kg/ha was obtained for the extensive culture of *P.monodon* in Ernakulam and Kollam districts in the present study. Jose *et al.* (2002) reported an yield of 732.5 kg/ha in 1995 and 647.5 kg/ha in 1996 from modified extensive culture system of *P.monodon* in Panangad region. In the present study a production of 761kg/ha was obtained from Panangad, higher than that reported by Jose *et al.* (2002). Prasad (2002) reported *P.monodon* yields of 886.58 kg/ha and 1,043.42 kg/ha from Chellanam and Kannamaly regions of Ernakulam district respectively. A production of 911kg/ha was obtained from the Chellanam region in the present study for the extensive culture of *P.monodon*. All the studies report higher production in Kannamaly and Chellanam areas than Panangad. Compared to other areas, farmers in Chellanam and Kannamaly areas are giving more care to pond preparation, eradication methods, nursery rearing, feeding and water quality management. The high production reported in this area was because of the adoption of these better management strategies.

Gopalan *et al.* (1978) compared *P.indicus* production from improved traditional system (504.16 kg/ha) and traditional system (268 kg/ha). Production of *P.indicus* under monoculture system was reported as 478.7 kg/ha (Felix and Sukumaran, 1988). The present study indicated a production of 1424 kg/ha for the extensive culture of *P.indicus*. The production obtained was less than that reported by Prasad (1999) from a low saline semi intensive system of Kerala (2557.16 kg/ha).

The mixed culture of *P.indicus* and *P.monodon* indicated an average yield of 628 kg/ha in the present study, higher than reported by Felix and Sukumaran (1988) for the mixed culture of *P.indicus* and *P.monodon* (407.5 kg/ha).

In the case of non disease affected extensive monoculture systems of *P.indicus* and *P.monodon*, net profit and net operating profit were higher for extensive culture system of *P.indicus*. Break-even output accounted for 43% and 68% of the total output for the extensive culture system of *P.indicus* and *P.monodon* respectively. Break-even output was achieved much earlier in extensive culture system of *P.monodon* (693 kg) than in extensive culture system of *P.indicus* which need to produce at least 846 kg to continue in the venture. Even though the total production cost was high for extensive culture system of *P.monodon* than the extensive culture system of *P.indicus*, the high unit price brought down the break-even production and increased the returns. The production cost per kg was higher for extensive culture system of *P.monodon* because of the high production cost and low shrimp production compared to that of *P.indicus*. Extensive culture system of *P.indicus* was more profitable with comparatively low production cost and gave higher additional returns for every rupee invested.

The inputs required per hectare were compared across the different shrimp culture systems and is given in Table-31. The traditional systems have the lowest input requirements. In the improved traditional system, eradication of predators and unwanted organisms in the nursery pond before stocking shrimp seeds, stocking of seeds and feeding them in the initial stages all require labour. These are totally neglected in the traditional system and hence the labour requirement is less. The extensive system is labour intensive than improved traditional since the feeding and water quality management are done on a more systematic manner throughout the culture period. The labour requirement reported by Leung and Gunaratne (1996) for extensive system was based on farms all over India. The current study was based on shrimp farms in Kerala alone. The states like Andhra Pradesh and Tamil Nadu utilise more labour for extensive shrimp culture systems resulting in higher labour requirement in the estimate by Leung and Gunaratne (1996) due to more systematic and scientific management practices adopted there.

Table-31. Comparison of input requirements in different shrimp culture systems

Shrimp culture system	**Feed requirement per ha(kg)**	**Labour requirement per ha (labour-days)**	**Source**
Traditional prawn filtration	-	81	Sathiadhas *et al.*, 1989
Improved traditional filtration system	79	118	Present study
Extensive system	1027	642	Leung and Gunaratne, 1996
Extensive system	2320	340	Present study

5.2.2. Economics of crab culture and fattening practices

Monoculture operations of mud crab in Philippines yielded 339 kg/ha (Lapie and Libero, 1979). Devaraj *et al.* (1999b) has reported a production of 780 kg/ 0.5 ha from mother crab farm at Tuticorin. Stickney (2000) had reported an yield of 485 kg/acre/crop of six months. Marichamy and Rajapackiam (2001) obtained a production of 780 kg/ 0.5 ha/ crop. Sathiadhas and Najmudeen (2004) reported an yield of 3.15 t/ha/crop in Vypeen Island, Kerala. The yield obtained from monoculture of mud crab in the present study ranged from 368 kg/ha/6months to 1143 kg/ha/6months with an average of 806 kg/ha/crop of 6months. In the present study an yield of 1.06 t/ha/crop was obtained from Vypeen. The average crab production in the present study has come down because of the lower production from Vallarpadom region. The farmers neglected the burrowing and crawling capacity of the crabs. Proper care was not taken to strengthen and maintain the bunds free of holes and cracks. Many of the farmers did not give proper fencing with bamboo poles and overhanging nets resulting in poor retrieval of crabs during harvest.

The production obtained in the present study was higher than that reported by Lapie and Libero (1979) and lower than all other studies due to the poor retrieval of crabs from Vallarpadom region. The net profit obtained in the present study (Rs.44, 000 /ha/6months) was higher than the net profits reported by Kathirvel and Vishwakumar (1993) and much lower than those obtained by Devaraj *et al.* (1999b), Marichamy and Rajapackiam (2001) and Sathiadhas and Najmudeen (2004). The low production obtained led to decline in gross earnings and low profits.

In crab culture, seed contributed to 35% of the total cost (Marichamy and Rajapackiam, 2001), 20% (Sathiadhas and Najmudeen, 2004) and 22% in the present study.

In crab fattening a production of 1.87 t/ ha/crop was reported by Devaraj *et al.* (1999b) in Tuticorin mother crab farm. Marichamy and Rajapackiam (2001) reported a production of 1.87t/ha/crop. Sathiadhas and Najmudeen (2004) reported an yield of 2.89t/ha/ crop. In the present study an average yield of 5.42 t /ha/6crops was observed from crab fattening practices.

When production for a single crop was compared, the current investigation observed lower production than reported by Devaraj *et al.* (1999b), Marichamy and Rajapackiam (2001) and Sathiadhas and Najmudeen (2004).

Marichamy and Rajapackiam (2001) realised a net profit of Rs. 2.19 lakh/ha/crop. Sathiadhas and Najmudeen (2004) reported net profit of Rs. 14.8 lakh/ha/year for 5 crops. The average net profits realized from crab fattening was Rs. 5.38 lakh/ha/6 crops in the present study. The unit price realised for the hard shelled crabs in the present study was only Rs. 273 whereas it was Rs. 300 in the investigation by Sathiadhas and Najmudeen (2004). The low production and unit price observed in the current study led to lower profits.

In crab fattening, seed contributed to 75.66% of the total cost (Marichamy and Rajapackiam, 2001), 81.45 % (Sathiadhas and Najmudeen, 2004) and 70% in the present study.

In spite of the high profitability, crab fattening and culture practice are not picking up as shrimp farming practices. The lack of consistent supply of seed crab is found to be the main reason for this. The crab culture is entirely dependent on the natural seed. Crab fattening utilises the water crabs available from nature and those which are rejected by export units. All these lead to the over exploitation of the natural population. In the present study it was observed that the crab fattening and farming practice were mostly done by people who were associated with export units which were marketing crabs. They only could manage consistent supply of baby crabs and water crabs from export rejections. Moreover crab farming requires lot of care and attention on the part of farmers as crabs escape easily from the ponds. Culling practice is to be done on a regular basis to avoid cannibalistic behaviour of crabs. The soft shelled water crabs are to be provided with shelters. Crabs have to be fed with fresh fish daily. Procurement of fresh fish daily is difficult compared to pellet feeds and other locally available feeds which could be stocked in advance. All these account for the low adoption rate of crab farming and fattening practices.

Establishment of commercial crab hatcheries can solve the seed problem and thereby lessen the stress on the natural population. Extension education programmes and field training programmes by research institutes and governmental agencies can accelerate the rate of adoption of this culture technique.

Of the 65, 000 ha of potential area suitable for brackish water aquaculture in the state of Kerala, hardly 20% is utilised for shrimp farming practices. Rest of the 80% of the potential area lie unutilised. If 10% of the unutilised area (5,200ha) is set apart for crab culture, 4,191t could be produced at the production rate achieved in the present study (806kg/ha). The gross revenue could be Rs. 1,106 million (at unit price Rs. 264). This would provide a total employment of 15.5 lakh labour days (at the rate of 298 labour days/ha).

5.2.3. Economics of milkfish culture practice

The yield from milkfish ponds under modular culture system ranged from 278 to 341 kg/ha/run in Philippines (Agbayani *et al.*, 1989) and was 398.43 kg/ha/92 days (Baliao *et al.*, 1999c). Tampi (1960) obtained a production of 212 kg/ha, James (1986) reported productions of 457 kg/ha/year and 857 kg/ha/year in Mandapam and Tuticorin in experimental conditions respectively. Gandhi and Mohanraj (1986) obtained 216 kg/ha and 852 kg/ha in fertilized and unfertilized ponds of Mandapam respectively. An average production of 1,746 kg/ha/crop obtained in the present study was higher than that reported by Sundararajan *et al.* (1979), James *et al.* (1984) at Mandapam and Anon (1985) at Ela Dauji and

Keshpur. The production reported by the present study is less than that reported for milkfish monoculture in Guam (Fitzgerald, 1988) and in Indonesia (Wilson, 1991).

In spite of the high production, profits and less disease risk, milkfish culture is not picking up as expected. Lack of proper awareness among farmers, inconsistent seed supply, lack of export market and lower unit price when compared to shrimp are all the contributing factors.

If milkfish culture is attempted in 10% of the unutilised area (5,200ha) in Kerala, 9,080 t of milkfish can be produced at a production rate of 1.746 t/ha which is reported in the present study. The revenue realised would be Rs. 572 million (at unit price of Rs.63). The potential for employment generation will be 8.22 lakh by milkfish culture at the rate of 158 labour days /ha.

5.2.4. Economics of different polyculture practices

Polyculture of brackish water fishes like *Chanos chanos, Valamugil seheli* and *Sillago sihama* in Mandapam yielded 1,864.5 kg/ha, 1,600 kg/ha and 1,377.8 kg/ha during 1979-80, 1980-81 and 1981-82 respectively (James *et al.*, 1984). Polyculture trials of brackish water fishes in Vyttila fish farm showed production in the range of 943 kg/ha/11 months to 2,189 kg/ha/13 months in annual crop and 674 kg/ha/6 months to 1321 kg/ha/7 months in short term crops (Mathew *et al.*, 1988). Polyculture of grey mullet and milkfish showed a production of 5.7 t/ha/crop and with improved management it yielded 7.2 t/ ha/crop (Sathiadhas *et al.*, 2003). Polyculture of fishes yielded an average of 5,647 kg/ha/8 months in the present study which is higher than that reported by other workers except by Sathiadhas *et al.* (2003). .

Thampy *et al.* (1988) has obtained an yield of 812.05 kg/ha/72 days for biculture of *P.monodon* and milkfish from Panangad in Ernakulam district. A production of 1,364.4 kg/ha was reported for polyculture of fin fishes and shrimp at Mandapam during 1979-80 (James *et al.*, 1984). An average production of 2,721 kg/ha/9 months obtained in the present study was higher than that reported by other workers.

If polyculture of crab, shrimp and fishes could be done in 10% of the unutilised brackish water area in the state (5,200 ha), it would generate employment of 61.1 lakh labour days. The total production from this area could be 25,662 t

(5,004 t of crab, 15,782 t of fish and 4,876 t of shrimp). The total revenue gained would be Rs. 4,015 million.

Polyculture of fishes and shrimps in an equal area could produce 10,895 t of fishes and 3,254 t of shrimps. This may provide employment of 14 lakh labour days and generate gross income of Rs. 1,947 million per annum.

Utilisation of 10% of the potential brackish water area lying idle for polyculture of fishes could easily raise Rs. 2,226 million with the production of 29,364 t of fishes. This would generate employment of 77 lakh labour days.

5.2.5. Economics of edible oyster farming

An average production of 425 kg meat was obtained by the rack and ren method of oyster farming in a 300 m^2 area at Dalavapuram in Ashtamudi lake during 1995 (Devaraj *et al.*, 1999b). The current investigation observed an average production of 279.45 kg meat from a single unit of rack and ren in Ayiramthengu region in Kayamkulam lake. The production ranged from 136 to 378 kg/unit/8-9 months. The rack and ren units in the study area ranged from 150 to 500 m^2. The production /ha worked out to 10.2 t in Ashtamudi lake (Devaraj *et al.*, 1999b) and 6.71 t in the current analysis. Although production was low at present than reported by Devaraj *et al.* (1999b), the net profit realised was comparable. This was because of the higher price obtained for the oyster meat in the present study (Rs.50/kg of shucked meat) than in the study by Devaraj *et al.* (1999b). The break-even production accounted for 68.5% of the total production and the input-output ratio was 1.46. All these show the profitability associated with less risk in edible oyster farming.

Edible oyster culture performed well in Ashtamudi and Kayamkulam lakes. The seed availability and growth has been confirmed in estuaries like Dharmadom, Korapuzha, Kadalundi and Chandragiri. The potential production from edible oyster culture, if 10% of these estuarine areas are set apart for this purpose, is indicated in Table-32.

Table-32. Production of edible oyster in 10% of potential area in estuaries-a projection

Estuary	Total Estuarine Area (ha)	Estimated production potential (t)
Ashtamudi lake	6,424	53,854
Kayamkulam lake	1,652	13,849
Dharmadom estuary	359	3,010
Korapuzha estuary	138	1,157
Kadalundi estuary	407	3,412
Chandragiri estuary	576	4,829
Total area	9,556	80,110

In one ha area, 24 edible oyster culture units of 300 m^2 can be accommodated. At this rate, 80,110 t of edible oyster can be produced. The revenue earned would be Rs. 320 million. This would provide employment of 8.94 lakh labour days. The labour requirement (39 labour days/unit), unit price (Rs.4) and average production per unit (3,493 kg) observed in the present study is used for the above estimation.

5.2.6. Economics of mussel culture

Kripa *et al.* (2001) reported a production of 750 kg mussels from a unit of 100 ropes in Ashtamudi lake. Modayil (2003) reported an average production of 25 t from a unit of 777 ropes in North Kerala. In the present study in Padanna and Ori regions in North Kerala, an average of 6.77 t was obtained from a unit of 500 ropes. The production ranged from 2 to 24 tonnes from units having 150 to 1,100 ropes. The net profit worked out in the present study was slightly higher than that obtained by Modayil (2003). Vipin Kumar *et al.* (2001) reported net profits ranging from Rs. 7,646 to Rs. 16,413 per unit for mussel farming, conducted by six SHGs in Kasargod district which was comparable with the results obtained in the present study.

The production obtained in the present study for mussel farming was low compared to that reported by Modayil (2003) but higher than that indicated by Kripa *et al.* (2001), when production was worked out for a single rope.

Seed alone contributed to 22 % of the total cost in mussel farming in the study conducted by Vipin Kumar *et al.* (2001), whereas in the present study it was 21%. Rope, coir and net cloth together constituted 42.5% of the total cost (Vipin Kumar *et al.,* 2001). In the present study it was only 38%.

Labour alone contributed to 61% of the total production cost in edible oyster farming where as in mussel farming, labour and seed contributed to 51% of the total cost. The labour productivity ratios also showed that edible oyster culture is labour intensive than mussel farming. The break-even production accounting for 65.1% of the total production and an input-output ratio of 1.54 showed mussel farming as a more profitable venture than edible oyster farming.

One ha of oyster farming needs labour requirement of 39 labour days and mussel farming 37 labour days. The main beneficiaries of bivalve development programmes were women. The women SHGs formed as a result of the successful demonstration programmes of CMFRI and financial support extended by Kerala government were trained on all aspects of farming. Following the great success of the self help groups in Padanna village of Kasargod district, other neighbouring villages also started mussel farming. Bivalve mariculture system in Kerala has been successful in bringing about women empowerment, additional food production and employment generation.

Mussel farming has been highly successful in North Kerala. The backwaters and estuaries like Padanna backwaters, Dharmadom estuary, Chettuva estuary, Kadalundi estuary and Ponnani estuary were found suitable for mussel farming. The projected production potential for some of our estuaries, if 10% of the area is set apart for mussel culture, is worked out and given in Table-33. If one ha area could accommodate 14 mussel culture units of $500m^2$, 340 ha could accommodate 4,760 units. These units could easily produce 32,187 t of mussel at the production rate indicated in the present study. Revenue of Rs. 177 million could be earned and the culture practice could make use of 1.76 lakh labour days.

Table-33. The estuarine area suitable for mussel culture and projected production

Estuary	**Total Area (ha)**	**Projected production potential (t) (10% area)**
Padanna backwaters	1,123	10,644
Dharmadom estuary	395	3,744
Chettuva estuary	714	6,767
Kadalundi estuary	407	3,858
Ponnani estuary	757	7,175
Total	3,396	32,187

At present the bivalves produced are marketed by the farmers themselves and by the Integrated Fisheries Project (IFP) in the domestic market. Part of the farmed mussels is exported. The domestic consumer demand for mussels and oysters has been low in India till recently. A well developed product awareness campaign and a marketing chain is to be developed within and outside the state to encourage the large scale adoption of bivalve mariculture (Modayil, 2003). Bivalves being filter feeders accumulate toxins, pollutants and microbes present in the water. Hence depuration (wherein bivalves are kept in water for 24-48 hours for lowering the microbial and pollution load) of the bivalves is required to maintain the quality of the product. Also the environment in which bivalves are cultured require constant monitoring for water quality parameters and should satisfy European Economic Community (EEC) guidelines. Most of the centres lack depuration facility and cold storage facility for boiled and shucked meat. These all affect the quality of the product. Stringent quality control measures should be adopted at all stages of production, processing, storage and transportation of bivalves.

Apart from estuaries and back waters, open sea and near shore areas can be utilised for mussel culture. Open sea mussel culture by raft method has been tried successfully off Narakkal. Feasibility studies done at Pallipuram in Vypeen Island for integrated bivalve farming also showed good results. Pilot scale studies are to be undertaken in other areas also, where sufficient mussel seed availability is reported. There is enormous scope to expand this culture system along Central and

North Kerala coast, Karnataka coast, Goa and Maharashtra coast. While selecting areas for mussel culture in open seas and bays, care should be taken to avoid any sort of hindrance to fishing operations and navigation by the culture installations like long line. Also the natural availability of mussel spat in sufficient amounts should be ensured in water bodies selected for the culture operations. If open sea mussel culture is attempted in at least 100 km coastal stretch of Central and Northern Kerala (after providing sufficient gaps in between long line units for fisher folk for fishing and for navigation purposes) covering an area of 5,000 ha and 50 km of coastline in Dakshina Kannada district of Karnataka covering an area of 2,500 ha, a minimum of 25,200 t of mussels can be produced by long line method at the minimum production rate of 10kg /m of seeded rope. About 12 long line units of 10 m length each can be accommodated in 1 ha area and 7 ropes can be suspended from a single unit with a seeded rope length of 4m. Gross revenue of about Rs. 1,386 lakhs could be obtained.

Currently there are no rules for ownership of water bodies. In Ashtamudi lake region of Kerala, people are considering the backwaters at the backyard of their houses as their own and are leasing out them to others for doing edible oyster culture. A system of leasing has to be developed for the back waters, near shore and open sea areas to give support to the farmers by the maritime states. Racks and rafts have to be erected without disturbing navigation in the waterways and traditional fishing rights.

5.3. Comparative Analysis of Economic Indicators

Table-34 gives a comparative picture of the various economic indicators of different aquaculture practices. Cost of production was maximum for crab culture system followed by extensive tiger shrimp culture system. When profit per kg was compared across the different culture systems, crab fattening system topped the list, followed by extensive tiger shrimp culture system and extensive Indian white shrimp culture system. Net profit and net operating profit were higher for crab fattening system. Although profit realised per kg was maximum for crab fattening system, the inconsistent supply of crab seeds prevent their large scale adoption. Although profit realised per kg was higher for the extensive culture system of tiger shrimp, the high production costs indicated the possible risk involved in case of a crop failure. Net operating profit of disease affected tiger shrimp extensive

Table-34. A comparison of economic indicators for different aquaculture practices

Key economic indicators	ET	EW	CC	CF	MC	EO	MF
Net profit/ha (Rs.)	92,986	1,23,407	43,982	5,38,237	37,544	4,401	12,989
Net operating profit/ha (Rs.)	1,47,877	1,61,812	64,319	5,87,557	47,146	6,018	14,928
Cost of production per kg (Rs.)	197	47	210	174	42	2.74	3.58
Profit/kg (Rs.)	92	63	55	99	22	1.25	1.92
Input-output ratio	1.46	2.33	1.26	1.57	1.51	1.46	1.54
Break even production (kg)	693	846	640	3,459	1,160	2,393	4,411
Break even production as % of total production	68	43	79	64	66	69	65

ET-Extensive tiger shrimp culture system

EW-Extensive Indian white shrimp culture system

CC-Crab culture system

CF- Crab fattening system

MC-Milkfish culture system

EO-Edible oyster culture system

MF-Mussel farming system

culture system was negative whereas all other shrimp culture systems affected by disease could manage a positive net operating profit. Extensive Indian white shrimp culture system on the other hand had moderate profit per kg and comparatively less production cost than the extensive tiger shrimp culture system.

When input-output ratios were compared extensive culture system of Indian white shrimp faired well. The less input requirement and moderate returns were the reasons for the good performance of this system. Break even production was only 43% of the total production for extensive culture system of Indian white shrimp. Extensive Indian white shrimp culture system showed least risk among the extensive shrimp culture systems.

Crab culture system was the first to achieve break-even production, followed by extensive tiger shrimp culture system and extensive Indian white shrimp culture system. When the percentage of break-even production to the total production was compared among the different culture systems, extensive Indian white shrimp culture system came first followed by crab fattening system. These systems were having better capacity to withstand unforeseen conditions than other systems. Establishment of commercial hatchery can go a long way in promoting crab culture and crab fattening to a greater extent since seed is the main constraint suffered by these systems.

The economic indicators clearly show mussel culture to be profitable than edible oyster farming. Although production cost per kg and break even production was low for edible oyster farming system, all other indicators favoured mussel farming.

5.4. Suggestions for Popularising Sustainable Aquaculture Practices

The total cost of production per hectare in all the extensive systems of shrimp farming exceeds one lakh except that of Indian white prawn where it approaches one lakh. The cost of producing one Kg of tiger shrimp in the extensive system was Rs 197 whereas it was only Rs 42 in milk fish. But the input-output ratios for the shrimp culture systems are much lower compared to crab fattening, milk fish culture and polyculture systems except that in extensive culture of Indian white shrimp. In spite of the possible risk of white spot disease in shrimp farms, the people are reluctant to move away from shrimp to these cultivable organisms because of the higher profits realised for a good crop that is unaffected by disease. This is mainly because of the high unit price of the shrimp compared to others. While one Kg of shrimp (20-25 count) fetches Rs 500 to Rs 410 in the export market, the Asian sea bass or grey mullet fetches a maximum of Rs 150. Crab commands a price of Rs 320 for excel grade (more than 800 g). The higher production cost in shrimp culture systems was mainly due to higher opportunity cost of the land. When farm surplus (including opportunity cost of land) is considered, the other culture systems do not appear to be remunerative as shrimp culture and hence provide no inducement by way of higher profits.

In brackish water fish culture and crab fattening, seed is a constraint and culture is entirely dependent on the wild seed. Hatchery production of seed on a commercial basis can help in popularising these culture practices in a phased manner.

The culture technologies for several organisms like edible oyster, mussel, etc. have been developed by the national research institutes like CMFRI in the back waters and open seas by erecting racks, rafts, long lines, etc. The maritime states of Karnataka, Goa and Kerala can utilise their near shore areas and open seas for mussel faming.

5.5. Policy Implications

There is ample scope for the development of diversified aquaculture practices. Government and public sector agencies like banks should take concerted efforts to promote diversified aquaculture practices. The overemphasis given to shrimp oriented aquaculture practices should be stopped. There should be policy support at the highest level for the promotion of diversified, location specific, need oriented aquaculture practices.

Appropriate water and land use policy should be framed at state government level for utilising water and land for various aquaculture practices. There should be clear cut guidelines for specific regions. Areas suitable for the development of bivalve mariculture in open seas and back waters and enclosure fisheries in open seas and calm bays should be identified, earmarked and government agencies should take up pilot scale culture experiments. Policies have to be developed on the extent of waters that could be leased, duration of lease agreement or permit, type of culture practice and cultivable organisms. The culture activities should not interfere with fishing activities, navigation and should not affect the ecology of coastal waters. Earmarking appropriate areas for each culture practice in the coastal zone towards landward and seaward side using GIS and remote sensing techniques will go a long way in promoting sustainable aquaculture practices.

One of the greatest constraints for the balanced development of different aquaculture practices is the lack of appropriate demand for the culture products in the internal market. In one sense the growth and development of aquaculture is entirely dependent on the export market. Although international demand is there for products other than shrimp, India's export market is oriented towards shrimp. Internal market coupled with export market should be developed for bivalves like mussel and edible oyster. Governmental agencies should come forward with improved marketing facilities. To ensure the quality of the product, bivalves have to be depurated before marketing and it will be ideal if the state government set up common facility at selected centres where farmers could depurate their product at a nominal rate. Provision for common storage facility of harvested mussel and oyster meat will help the farmers. Internal marketing avenues for raw and value added products should be created with governmental support.

Adequate measures should be taken for pollution control wherever dumping of waste is there. Areas where dumping or discharge of waste should not be allowed are to be earmarked by Pollution Control Board or other competent bodies. In areas where pollution is inevitable, polluter pay principle is to be adopted. Intervention of Central Government at the highest level, with the participation of respective state governments and local bodies at grass root level, with PCB being vested with the power for overall control is required to contain the pollution problem. Aquaculture farmers should follow the directives of Aquaculture Authority of India for minimising the negative effects generated by the culture practices.

Decision is to be taken at policy level for intense mangrove afforestation programmes in the existing government land/waste land in the coastal belt of the country. This will protect the nursery and breeding grounds of several aquaculture species and will also help to prevent soil erosion.

SUMMARY

SUMMARY

Coastal mariculture in the strict sense has not taken off in India due to many techno-bio-socio-economic factors. Hence a thorough economic analysis of coastal aquaculture in Kerala with specific reference to externalities has been attempted in the present study. The sample design of the study covers 208 farms practicing different types of mariculture in four districts of Kerala and the data were collected during 2001-03.

Pollution was found to be the externality with significant effect, seriously affecting shrimp culture. This is clearly indicated by the reduction in production (37%) and reduced lease amount of Rs. 7,500/acre over the last eight years (1995-2003) in the study area. Although effluent standards have been set for the seafood industry and processing units, the absence of proper controlling and monitoring mechanism have led to the free flow of pollutants into the water bodies. The aver-def expenditure incurred for one acre of shrimp farm was Rs. 615.6/ annum. The contingent valuation technique showed that about 50% of the farmers were willing to pay for getting good quality water for shrimp culture by establishing a common treatment plant. About 33 % of the farmers opined that polluters have to pay. The hedonic analysis showed that water quality index and water exchange index were significant at 1% level in determining land value, clearly indicating the influence of water characteristics. In Kerala, polluter pay principle in general was found to be more effective in dealing with externalities like pollution. Top priority should be given to establish treatment plants by the industrial units considering the long term benefits. Local bodies like Panchayats are to be given the rights for monitoring of these treatment plants to avoid environmental degradation.

The total extent of mangrove areas in and around Cochin backwaters and Vembanad lake reduced from 70,000 ha in 1975 to a mere 455 ha in 2002. The mangrove areas were converted for various purposes like coconut plantations, shrimp culture, reclamation and other development activities. About 21.5% of the sample farms were built on mangrove areas. Mangrove destruction due to shrimp farming was found to be significant in the present study. The cost benefit analysis and economics of land use options in mangroves studied by different workers showed clearly that mangroves are not waste lands to be reclaimed. The CRZ

notification and the connected rules and amendments take care of the conservation and management of mangrove ecosystems. Remote sensing and GIS used to assess and monitor the health of mangroves are infact effective tools in formulating appropriate management strategies for their conservation. The growing awareness of the people on the goods and services of mangroves and mangrove afforestation programmes can go a long way in conserving and managing mangrove ecosystems.

The greatest calamity faced by the farmers during the study period was white spot virus onset culminating in severe economic losses (2001-2002). A reduction in yield to the tune of 44% was observed in the improved traditional systems and 47% in extensive systems. A total revenue loss of about Rs.1,742.4 crores (US$ 360 million) was estimated due to disease problems for the Indian shrimp farming sector in the year 2001-02. About 200 lakh labour days were lost due to disease alone indicating that nearly 1 lakh people could have been employed on a regular basis for 6 months in the absence of this disease. Considering the forex earnings and employment opportunities, government should come forward to help the shrimp farmers by way of insurance schemes with low premium or subsidies. The resources for the same can be even raised by imposing aquaculture cess on marine product exports.

When the improved traditional shrimp culture practices were compared, average production per hectare was 978 kg in improved traditional seasonal ponds and 836 kg in perennial ponds. A net profit of Rs.38,000 was obtained from seasonal farms and Rs. 17,163 from perennial farms from one hectare with cost of production per kg of Rs. 57 in the former and Rs. 99 in the latter.

In the extensive shrimp culture systems, average shrimp production per hectare was 669 kg in the biculture system of tiger shrimp and Indian white shrimp, 1,016 kg in the tiger shrimp monoculture system and 1,963 kg in Indian white shrimp monoculture system. The net profits realised per hectare from biculture system, tiger shrimp monoculture system and Indian white monoculture system were Rs.17, 942, Rs. 92,986 and Rs. 1, 23,407 respectively. The production cost per kg was Rs. 198, Rs.197 and Rs. 47 for biculture system, tiger shrimp monoculture system and Indian white monoculture system respectively.

In the crab culture system the average production per ha per six months was 806 kg and in crab fattening system it was 5,423 kg. The net profit per ha for crab culture and crab fattening were Rs. 43,982 and Rs. 5,38,237 respectively. The production cost per kg for crab culture and crab fattening were Rs. 210 and Rs. 174 respectively. The milkfish culture system reported an average production of 1,746 kg/ha. The net profit obtained was Rs. 37,544 per ha. The cost of production per kg was Rs. 42.

The polyculture system with fishes obtained an average production of 5,647 kg/ha, the one with crab, fish and shrimp reported 4,935 kg and polyculture system with fishes and shrimp yielded 2,721 kg. The net profit reported per ha was Rs. 2, 02,269 from polyculture system with fishes, Rs. 3,14,662 from the system with crab, fish and shrimp and Rs.1,49,353 from polyculture system with fishes and shrimp. The cost of production per kg was Rs. 35.6, Rs. 96 and Rs. 59.4 for the three polyculture systems respectively. Polyculture of fishes indicated lowest production cost and moderate profits among the three polyculture systems.

The edible oyster and mussel farming reported the possibility of an average production of 11,643 kg and 13,544 kg respectively from a single unit of 1000 m^2. The net profit realised from a single unit of edible oyster and mussel farming was Rs.14,670 and Rs. 25,978 respectively. Cost of production was Rs. 2.74 and Rs. 3.58 per kg of edible oyster and mussel respectively. Mussel culture was found to be profitable than edible oyster farming.

India being a labour abundant country, labour intensive culture techniques should be given national priority. From the employment point of view, polyculture systems with fishes, polyculture system with fishes, crab and shrimp, extensive shrimp biculture system and extensive Indian white shrimp culture system should be given priority. Production and profit wise also polyculture systems faired well.

The constraints like absence of a commercialised hatchery to provide consistent seed supply, lack of proper marketing channels and negligence in quality control aspects, act as stumbling blocks in popularising diversified coastal aquaculture practices. The legal problems in leasing out back waters and open sea for bivalve mariculture practices should be also solved by framing adequate leasing policies.

Of the 65, 000 ha of potential area found suitable for brackish water aquaculture in the state of Kerala, hardly 20% is utilised for shrimp farming practices. Although projections have been worked out for revenue and employment generation by setting apart 10% of the potential area for crab culture, milkfish culture and polyculture systems each, all these may not be possible in a rational and realistic outlook within the next five year period. But there is enormous scope for the expansion of polyculture practices in another 30% of the potential area in Kerala. This would easily generate an additional revenue of Rs. 8,188 million and employment of 152 lakh labour days. Similarly if edible and mussel culture is attempted in 10% of the potential area of Kerala, this would generate additional revenue of Rs. 497 million and would provide employment of 10.7 lakh labour days. About 84,500 people could be regularly employed for six months in these polyculture systems and 5,940 in bivalve culture systems.

The need for a uniform fisheries act or aquaculture regulation for the state of Kerala is overdue to avoid different regions being governed by different rules. Extension of leasing period of seasonal prawn filtration fields up to May 14th (one more month) to allow more growing period for shrimp should be taken into consideration. Shrimp farmers are to be given legal protection for their crops during the same period. Reclassification of agricultural lands in the revenue records should be carried out. Land unsuitable for agriculture should be removed from that category and should be brought under aquaculture category so that ecofriendly aquaculture practices can be done in these lands rather than lying idle. *Pokkali* fields lying idle for various reasons in the monsoon season should be brought under ecofriendly fish culture practices in a phased manner. Public should be made aware of the demerits of reclamation of *pokkali* lands for other development purposes.

In Kerala, the traditional aquaculture systems lie below the mean sea level in natural intertidal zone and hence the problem of salinisation of drinking water and agricultural lands by shrimp farming does not arise. In areas where farming is attempted above the mean sea level, by taking in saline water through channels or pumped through pipes, such problems prevail. Identification and earmarking of areas appropriate for each culture practice should be done using GIS and satellite imaging techniques. Provision of adequate buffer zones should be made to avoid saline intrusions wherever possible. Suitable cropping pattern with saline resistant varieties can be taken up in affected areas.

Economic analysis of coastal mariculture indicated the vast scope of enhancing fish production by adopting appropriate location specific culture enterprises. The enormous positive benefits generated by coastal aquaculture/ mariculture surpass the negative externalities. Cost-benefit studies and environment impact analysis (EIA) of different production systems should be taken up before venturing any culture practice. Ethos of "responsible aquaculture" is the only way to internalise the negative externalities arising from coastal aquaculture. Coastal villages still remain as the most backward regions of our country. Most of the near shore coastlands are saline infected barren wastelands having little scope for promoting agricultural activities due to many constraints. There is no alternative avocation available to vast majority of stakeholders other than fishing and fishery related activities. Fisher folk are not inclined to shift their occupation other than fisheries or migrate from the coastal villages. Nature's gift is the potential to promote eco-friendly mariculture in these regions. Integration of mariculture with inshore fisheries in open waters and coastal aquaculture in landward regions may provide the much needed 'acceleratory and multiplier" effect on the growth of coastal economy. The key economic indicators and overall assessment of externalities clearly favour the growth of coastal aquaculture and mariculture in India as it supplements the employment opportunities and pave the way for coastal rural prosperity.

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APPENDICES

APPENDICES

APPENDIX I.

ECONOMIC ANALYSIS OF EXTERNALITIES IN COASTAL MARICULTURE

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, KOCHI

SCHEDULE - 1

<u>GENERAL INFORMATION ON DIFFERENT MARICULTURE PRACTICES</u>

Code number :

Date of enumeration:

1. Name and address of the farmer

Village ....

District ....State ....

2. Area under culture
3. Type of culture & nature of culture system
4. Species under culture
5. Stocking density
6. Source of seed
7. Duration of culture period
8. Average depth
9. Source of water
10. Year of construction and cost

11. Farm preparatory steps

12. Eradication methods

13. General social problems

14. Environmental problems

15. Input supply problems

    1. Seed

    2. Feed

    3. Labour

16. Biological problems

17. Marketing constraints

18. Source of finance

19. Undergone any training programmes

20. Remarks

Signature and name of the investigator

Date

Place

APPENDIX II.

ECONOMIC ANALYSIS OF EXTERNALITIES IN COASTAL MARICULTURE

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, KOCHI

SCHEDULE - 2

COSTS AND EARNINGS OF SHRIMP / CRAB / FISH CULTURE PRACTICES

Code number:

1. Land cost and opportunity cost of the land or lease value
2. Number of seed stocked
3. Cost of seed
4. Transportation cost for seed
5. Costs involved in field preparation
    - Labour charges

      .... man days..............wages / day
    - Cost of lime, toxicants and fertilizers

      .... quantity .... Rs. / kg ....
    - Cost of sluice gate (incurred by himself / owner) ....

      .... lifespan (years)
    - Labour charges for sluice gate installation

      .... man days .... wages (Rs. / day)
    - Fuel costs for drying of pond by pumping out water

      .... litres .... Rs. / l
6. Cost of pump............................ (Lifespan)...............
7. Price of generator .... (Lifespan)................
8. Electricity charges
9. Quantity of feed used

10. Cost of feed

11. Transportation charges for feed
12. Cost of feeding trays and other equipment if any
13. Cost of antibiotics, growth promoters etc
14. Cost of equipments used for monitoring water quality
15. Salaries of permanent staff.........No.s ....salary ....months
16. Labour costs involved in harvesting

    .... man days......... wages / day
17. Fuel costs for pumping out water......litres......Rs./ l
18. Cost of ice
19. Harvesting equipments like net

    .... kg.............. Rs / kg.............. (Lifespan)
20. Transportation charges of the produce
21. Cost of shed......... (Lifespan)...........
22. Consultation fees.............
23. Family labour ....man days.................wages
24. Any other costs (specify)

25. Yield (shrimp / crab / fish)

	Count	Quantity	Price / kg
Shrimp			
Crab			
Fish			

27. Externalities either generated by coastal aquaculture or by other activities which affect aquaculture:

   - Destruction of mangrove vegetation
   - Pollution and effluent discharge
   - Conversion of agricultural land for aquaculture purpose
   - Decrease in paddy yield
   - Displacement of labour
   - Salinisation of drinking water
   - Over exploitation of natural seed
   - Social problems like flooding due to blocking of drainages
   - Denial of access to open sea
   - Social problems in sharing of resources with traditional fishermen
   - Health problems in workers due to effluents, chemicals etc.
   - Perturbation of critical habitats
   - Any other externalities (specify)

28. Remarks

Signature and name of the investigator

Date

Place

APPENDIX III.

ECONOMIC ANALYSIS OF EXTERNALITIES IN COASTAL MARICULTURE

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, KOCHI

SCHEDULE - 3

ECONOMIC ANALYSIS OF OYSTER OR MUSSEL CULTURE PRACTICES

Code number :

Date of enumeration:

1. Name and address of the farmer or the group involved:

2. The species cultured and the type of the culture system:

3. Duration of the culture period:
4. The water body in which culture is carried out:
5. Area of the farm:
6. Cost of bamboo: .... (Life span).........
7. Cost of nylon rope and coir rope:

8. Cost of net waste, bandage cloth etc:

9. Transportation cost for the above items:

10. Cost of shell (For ren)

11. Labour cost for rack and ren installation:

    ....man days .... wages/day

12. Seed cost (For mussel faming alone):

13. Transportation cost of seed (For mussel faming alone):

14. Labour charges for cleaning, shell drilling etc .... man days .... wages/ day

15. Labour charges for harvest..................man days.........wages/ day

16. Cost of boat and its life span or boat rent:

17. Family labour ....man days

18. Yield in kg:

19. Price per kg:

20. Remarks

Signature and name of the investigator

Date

Place

APPENDIX IV.

ECONOMIC ANALYSIS OF EXTERNALITIES IN COASTAL MARICULTURE

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, KOCHI

SCHEDULE - 4

ECONOMIC ANALYSIS OF THE EXTERNALITY- POLLUTION (Pre-survey)

Code number :

Date of enumeration:

1. Area under farming:
2. Species farmed and whether improved traditional / extensive / semi-intensive system
3. Value of land or lease amount:
4. Age of the farmer
5. Income status of the farmer-low / medium / high

   Low - Below Rs. 50,000

   Medium -Between Rs. 50,000-75,000

   High - Above Rs. 1,00,000
6. Educational qualification of the farmer
7. Source of pollution
8. Extent of pollution- low/ medium/serious
9. Changes in productivity due to pollution
10. Increased expenses due to

    a) The use of chemicals to improve water quality

b) Pumping or water exchange

c) Lab charges, technician salary, extra labour charges

11. Farming area abandoned due to pollution

12. Reduction in lease amounts/ land value due to pollution problem

13. Shifting of occupation from aquaculture due to pollution problem

14. Any plans to change/ changed the species cultured

15. Proximity of the farm to the bar mouth

16. Level of farmers perception about the pollution problem - poor/ medium/ good

17. Proximity to road

18. Water exchange index-poor/ medium/ good

19. Water quality index-poor/ medium/ good

20. Canal from which water is taken into the farm

21. Any health problems on contact with polluted water

22. The farmers' willingness to pay for establishing a treatment plant to get good quality water for aquaculture as aquaculture tax .... Rs./acre/year

23. Reasons for quoting this amount/ or for not willing to pay

24. Agency which you favour to be entrusted with the task of collecting the amount from farmers as aquaculture tax

25. Remarks

Signature and name of the investigator

Date

Place

APPENDIX V.

ECONOMIC ANALYSIS OF EXTERNALITIES IN COASTAL MARICULTURE

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, KOCHI

SCHEDULE - 5

ECONOMIC ANALYSIS OF THE EXTERNALITY- POLLUTION (Final survey)

Code number :

Date of enumeration:

1. Area under farming:
2. Species farmed and whether improved traditional / extensive / semi-intensive system
3. Value of land or lease amount:
4. Age of the farmer
5. Income status of the farmer-low / medium / high

    Low - Below Rs. 50,000

    Medium -Between Rs. 50,000-75,000

    High - Above Rs. 1,00,000
6. Educational qualification of the farmer
7. Source of pollution
8. Extent of pollution- low/ medium/serious
9. Changes in productivity due to pollution
10. Increased expenses due to
    a) The use of chemicals to improve water quality

b) Pumping or water exchange

c) Lab charges, technician salary, extra labour charges

11. Farming area abandoned due to pollution

12. Reduction in lease amounts/ land value due to pollution problem

13. Shifting of occupation from aquaculture due to pollution problem

14. Any plans to change/ changed the species cultured

15. Proximity of the farm to the bar mouth
16. Level of farmers perception about the pollution problem - poor/ medium/ good
17. Proximity to road
18. Water exchange index-poor/ medium/ good
19. Water quality index-poor/ medium/ good
20. Canal from which water is taken into the farm
21. Any health problems on contact with polluted water

22. The farmers' willingness to pay for establishing a treatment plant to get good quality water for aquaculture as aquaculture tax

Rs.100	Yes/No
Rs.200	Yes/No
Rs.300	Yes/No

Rs.400	Yes/No
Rs.500	Yes/No
Rs.600	Yes/No
Rs.700	Yes/No
Rs.800	Yes/No
Rs.900	Yes/No
Rs.1000	Yes/No
Rs.1100	Yes/No
Rs.1200	Yes/No

23. Reasons for quoting this amount

24. Agency which you favour to be entrusted with the task of collecting the amount from farmers as aquaculture tax

25. Remarks

Signature and name of the investigator

Date

Place