Reconciling Environment and Economics: Executive Summaries of EERC Projects

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MARINE ECOSYSTEMS AND SUSTAINABILITY

An Economic Analysis of the Sustainability of Marine Fish Production in Karnataka

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Introduction

Continued economic productivity of fisheries depends upon the current biological and economic conditions, and sustainability implications of continuing current exploitation rate and methods. The 1990s have seen global crises in marine fisheries, and the maritime state of Karnataka is no exception. The modernisation of fishing fleets and the uncontrolled expansion of fishing efforts are the main reasons for declining growth rates of total marine fish production. In the course of the past five decades, the annual marine fish production of India increased from about 0.9 million tonnes in late 60s to the current level of 2.6 million tonnes. The total fish production increased from 75,793 tonnes in 1969 to 2,51,012 tonnes in 1989, and started declining thereafter with a production of 1,39,676 tonnes. The contribution of annual pelagic fish production varied between 80 percent in 1975 to 50 percent in 1994. The percentage of demersal fishes varied between 9 percent in 1971 to 30 percent in 1983. Crustaceans, which accounted for a small proportion, during 1970s increased its share to 25 percent in 1987 and declined thereafter.

The marine fisheries are one of the major industries in coastal Karnataka. In the state's exclusive economic zone of 87,000 sq. km., fishery resource is estimated to yield 425,000 tonnes per year. The extraction of fishery resources has undergone major changes in the last few decades. In the 1950s, the state fisheries were characterised by small-scale with fixed fishing gears such as shore seines. The total catch was low and the fish caught were destined for local markets. However, in the early 60s there was a shift in preference towards more mobile fishing gears, which allowed the fishermen to actively pursue fish. The emphasis of the state program was to increase fish production for domestic consumption and export. This had been sought through various devices such as motorisation, port development and providing new boats and fishing gears. As a result, during the period from the 1970s to the early 1990s, fish catch increased at a record rate and became highly diversified in terms of species landed. As of now, more than 80 species are commercially harvested throughout the state's coast. Fishing technology also was highly diversified. As per the latest estimates, there are more than 2,098 shrimp trawlers, 378 purse-seiners, 1,180 gill-netters, 1,179 other mechanised boats, and 11,958 non-mechanised boats in Karnataka.

The fishery modernisation in the state has had mixed results. On the one hand, despite the growing size of the fishing fleet, the industry has by no means attained its full potential. For instance, Karnataka's average annual fish landing has remained around 142,000 tonnes in the last 10-15 years, much below its estimated total annual potential of 425,000 tonnes. On the other hand, there are growing signs of biological and socio-economic unsustainability that threaten the coastal fisheries. The introduction of trawlers has adversely affected other shore seines' and its own catches. The Karnataka State Department of Fisheries reported symptoms of over fishing in shrimp and other high valued fishes. Also, trawlers are alleged to have interfered with the fishing rights of traditional, small-scale fishers in the near shore areas, leading to rising social rifts between the two groups. The traditional rampani nets, which once accounted for 50-60 percent of the annual catch, have almost disappeared. There were episodes of clashes over resource users, which sometimes resulted in the loss of assets.

In the meanwhile, realising the possibility of overexploitation, particularly along the inshore, the state government enacted the Karnataka Marine Fisheries (Regulation) Act (KMFRA) as early as 1986. The Act empowers the State Fisheries Department to regulate fishery through licensing. The overall package seems to prescribe limited entry, a standard policy instrument. The Act has also banned mechanised fishing during the monsoon, which is the breeding season for most of the pelagic species. In addition to compulsory registration of vessels, this legislation imposed restrictions on fishing in specified areas, and on the number of vessels in specified areas and seasons. The compulsory registration of all the vessels, both mechanised and non-mechanised, also served as an authentic record on the number of various types of fishing vessels operating from the coast.

After 15 years of KMFRA implementation, a number of issues still confront fishery managers in Karnataka, including the lack of understanding of the fishery-wide impacts of regulations, conflicts between small and commercial fishers, and declining stocks of certain fishes. Fishery regulation has never been based on a scientific understanding of how certain policy instruments might affect the biological sustainability and economic viability of target species. Species vary widely in their economic and biological productivity. Also, the technical efficiencies of different gear types are not the same. In a fishery that produces multiple species obtained through different types of gears, there could be technical interactions among species and gear types. The limited-entry policies of KMFRA do not seem to recognise these technical interdependencies among species and gears, or the productivity differences across gear types. Such policies only have the illusion of keeping control over the total fishing effort. They could still fail to stem the depletion of certain primary or secondary target species. No effort has been made as yet to analyse the biological and economic effects of alternative management policies on different species.

Objectives

This research is an attempt to address certain management-related questions concerning the process of fishery modernisation and the concurrent regulations in Karnataka. The key research questions explored include:

- Assess the current biological and economic conditions of commercially important species in Karnataka.
- Evaluate the future sustainability implications of the current level of fishing effort.
- Suggest policy options for fishery management.

Methodology

In order to address the above objectives, we need to develop appropriate analytical tools to first estimate stocks and stock-effort-catch relationships, and then to characterise the optimal mix of fishing fleets under alternative management scenarios. Such an exercise is hoped to better inform the management process in its effort to move toward more sustainable fishing.

Data Sources

The data for the descriptive and modelling part of Karnataka marine fisheries comes from mainly two sources. The landings and effort data for the period from 1994-98 was drawn from Central Marine Fisheries Research Institute (CMFRI). The second set of data on costs and earnings, harvested price, labour share and income, and other economic parameters were estimated through a sample survey of the fishery vessels in coastal Karnataka. In this study, the data was collected for the two coastal districts namely Dakshina Kannada and Udupi districts for the fishing season of 1999-2000. The data on costs of fishing trips, capital and fixed costs of crafts and gear was collected from 15-20 fishing units in each vessel class to estimate the economic efficiency of each selected vessel. The construction of multi-species optimisation model required three types of data: (a) economic data consisting of market prices, fishing costs, storage capacity and labour requirement; (b) technological data including vessel-to-species effort conversion parameters, effort standardisation parameters, catchability co-efficient and annual available fishing capacity; and (c) biological data that included initial period stock estimates and growth parameters.

Market price data for the selected species is collected from field observations. The costs per actual fishing hour (AFH) are computed using data from a primary survey of different fishing firms. Based on this computation, the unit fishing costs are estimated at in Rs/actual fishing hours 410, 919, 460, 70, and 100 for technology classes multi day trawl nets, purse seines, trawl nets, outboard motor boats, and non-mechanised boats respectively. However, these costs represent the cost of fishing efforts that landed all the reported species in the port. For certain individual vessel classes, particularly for outboard and non-mechanised nets, the species included in the model represent a small portion of the vessel's total effort. The unit costs are therefore prorated based on the proportion of the vessel's effort directed toward the model species.

Model Development

In this study, we employ both single-species static models and multi-species dynamic (mathematical programming) models. The purpose of the first set of models is two-fold: first, these models would enable us to assess the sustainability of individual species at the state level; and second, these models provide various techno-economic and biological parameters, and stock estimates required for the multi-species programming model. The multi-species model is designed for individual port-levels. A state-level multi-species model would not be inappropriate since there is a large variation across ports.

The results of the estimation of maximum sustainable yield and maximum economic yield indicate that the difference between cost and price reflecting the surplus is highest for pomfrets and shrimp, followed by sharks and rays. Interestingly, the current harvest levels for these species have far exceeded the sustainable yield. Motivated by the higher economic surplus, the fishermen try to harvest more, resulting in biological unsustainability of these resources. The estimated values of yield, effort and cost of MSY and MEY levels for the selected demersal species against the harvest quantities of the base year 1998 were studied. The results show that for most of the species, the current harvest has exceeded both MEY and MSY, indicating some degree of overexploitation. For example, by spending 19,183 actual fishing hours, the fishery could have harvested 8,400 tonnes of MEY and 8,327 tonnes of MSY. However, by spending almost the same level of effort (19,719 actual fishing hours), the current yield (1998) was only 2,516 tonnes, which represents the excess of fishing effort and hence, societal loss. In the case of many other species, the current harvest quantity is more than the MSY and MEY.

Model Results

The estimated value of MEY and MSY pelagic fishes shows that for some of the species such as mackerel, the symptoms of unsustainability are very clear. By spending 67,582 actual fishing hours, an MEY level of 30,848 tonnes could have generated maximum revenue surplus. The comparison with the 1998 yield and effort shows that by spending almost the same level of fishing effort (65,288 actual fishing hours), the yield is 27,257 tonnes, indicating that the fishery is operating at the maximum economic yield level and any further increase in effort could lead to decline in the fishery rent.

The sustainability of demersal species in value terms under three scenarios is estimated. Scenario 1 and 2 represent the value of the catch with the restriction of MSY and MEY. This means that if the fishery manager were to impose the restriction, the actual total catch value should have been only Rs.786.01 million of MSY or RS.736.79 million of MEY. However, the actual (1998) harvest value for most of the species have exceeded both MSY and MEY levels, representing excess harvest value over and above the sustainable level, with a total of Rs.1,540.32 and Rs.1,615.41 of MEY and MSY respectively. The results indicate that for tunnies, seer fish and stolephorus, there has been excess harvest over and above the sustainable level. Though an accurate estimation of sustainability for these species is difficult because of their highly fluctuating nature, the results indicate that they are also under threat from the viewpoint of sustainability.

The multi-species optimisation model is simulated for the Mangalore port. The Mangalore port is the largest fishing port in Karnataka, constituting 35 percent of the state's total fish landing in 1998. Seventeen of the most important species, which contributed more than 1.5 percent of the total port landing during 1994 to 1998, are included in the model. Based on the 1998-reported catch, these 17 species constituted more than 85 percent of the total fish catch in Mangalore. The top five species harvested in 1998, in the order of their weight, are breams, Indian mackerel, stolephorus, sardine and cephalopods. For the same period, more than 10 different types of fishing vessel technologies are reported to have been employed. For the purpose of this study, these vessel classes are regrouped into five homogenous vessel classes: mechanised trawlers nets (MTN), purse seiners (PS), trawler nets (TN), out-board fishing nets (OBU), and non-motorised boats (NMB).

The catchability coefficients for most model species of the Mangalore port are assumed to be the same as the estimates developed for the Karnataka state in the previous sections. For certain model species, state-level estimates are not available. The catchability coefficients of most closely related species are used for such species. The annual capacities of fishing vessels in AFH are assumed at the 1998 levels.

The initial year exogenous stock levels are computed using the Fox model. For using the Fox model, the 1998 levels of standardised efforts are first computed for each model species of Mangalore port. These standardised effort values along with the estimates of catchability co-efficient and the observed quantities of species catch are plugged into the Fox model equation to estimate the initial year stocks. However, when we run the baseline simulation model, our goal is to make sure that the model-generated catch values come as close to matching the observed catch values for the year 1998. Of the four variables above, catchability coefficients are estimated using the state-level data of 10 years, which we think are more reliable than the initial year stock estimates for Mangalore. The 1998 observed catch and effort values are certainly more accurate than the unobserved stock estimates. Therefore, for the purpose of this analysis, we calibrate the initial exogenous stock values so that the baseline model generates species catch distribution as close to the 1998 observed catch distribution as possible.

The mathematical programming model is solved using the Generalised Algebraic Modelling System (GAMS) software. This software has a routine for solving non-linear programming models. The model is run for a period of 10 years with annual increment. The baseline model has a total of 663 equations (belonging to 11 separate blocks of equations), 563 variables, and 2,362 non-zero elements. Several sensitivity analyses are also carried out to evaluate various management and policy scenarios.

Before a model can be used for any meaningful policy and management analyses, the model results must first be validated with reference to some historical or observed outcomes that the model is trying to predict. In an optimisation model like the current one, validation cannot be done by simply comparing the model-estimated values with some historical values, since the model optimises effort and catch. The reason is that the observed values may not be optimal to begin with. Alternatively, we force the endogenous effort levels for all the model years to be equal to the observed effort level of 1998. Then we compare the 1998 model catch values and the observed catch values. We call this the baseline simulation. This effort restriction on the model also allows us to understand how harvesting at the current effort level would impact the sustainability of the fishery stock and catch.

A comparison of the 1998 observed catch and the model-estimated catch is made. For most species, the differences between the model and observed levels of 1998 catch are within 11 percent. For ribbonfish and stomatopods, the difference is around 18 percent of the observed level. For pomfrets, there is a wide relative gap between the two values. There was a wide year-to-year fluctuation in the pomfrets catch during 1994 to 1998. Also, this is one of the least significant model species in recent years. There may be errors in the specification of the unobservable biological parameters, and errors in collecting the third party data on catch and effort. Given these factors, we consider the model's overall performance quite satisfactory.

In the baseline simulation, the stocks of 9 out of 17 model species will be declining over time. These are Indian mackerel, rock cods, bream, ribbonfish, other carangids, black pomfrets, prawns, stomatopods, and cephalopods. Stocks of six species - sardine, stolephorus, thryssa, other perches, and soles - will be increasing. Stocks of two other species - other sardines and scads - remain stable. The most interesting result to watch is mackerel. This species would become most unsustainable in terms of both stock and catch in 10 years if the exploitation continues at the current effort intensity. Mackerel, which is only second to breams in catch with 5,246 tonnes in 1998, experiences more than 40 percent reduction in catch. Similarly, other species that suffer a drastic decline in stock and catch are prawns, stomatopods, and cephalopods.

The baseline harvesting results in total market revenue over a 10-year period of little over Rs.4,929 million, whereas the total cost of harvesting is as high as Rs.4,844 million. That leaves a net fishery rent of only Rs.84 million or 1.7 percent of the total market revenue. Relative to the total market revenue, the rent margin under the current harvesting scenario is insignificant. The crewmembers salary is estimated at Rs. 1,391 million or 28.23 percent. Since trawlers, both mechanised and multi-day, catch mostly the demersal species, the trawler industry would more likely be affected by this decline. Concurrently, the employees of this industry would be adversely affected too.

Our next goal is to run the model to characterise the optimal combination of vessel efforts. We run the simulation again without forcing endogenous effort values on the model, like in the baseline run. The only restriction we would put is the minimum and maximum constraint on the effort. The minimum effort constraint is included to reflect the political reality that no single vessel class could be completely eliminated from the fishery. The maximum constraint is necessary to avoid the model to become unbounded. Also, there are real-world capital constraints on the limits to which fishery capital can expand in a given time period. The maximum fishing efforts are assumed to be 25 percent above the 1998 observed levels for all vessel class except NMB. For the latter, the effort restriction is placed at twice the current level. The minimum efforts are assumed at 50 percent of the current level.

The multi-species optimisation model is simulated for the Mangalore port. The Mangalore port is the largest fishing port in Karnataka, constituting 35 percent of the state's total fish landing in 1998. Seventeen most important species, which contributed more than 85 percent of the total port landing during 1994 to 1998, are included in the model. Based on the 1998-reported catch, these 17 species constituted more than 85 percent of the total fish catch in Mangalore. The top five species harvested in 1998, in the order of their weight, are threadfin breams, Indian mackerel, stolephorus, sardine and cephalopods. For the same period, more than 10 different types of fishing vessel technologies are reported to have been employed. For the purpose of this study, these vessel classes are regrouped into five homogenous vessel classes: mechanised trawlers nets (MTN), purse seiners (PS), trawler nets (TN), out-board fishing nets (OBU), and non-motorised boats (NMB). (Repeat of para on pgs 6-7)

The results of the optimal harvesting simulation presented in the report show that while there is still some degree of overfishing in some cases, the stocks of all but four species either increase or remain stable. Indian mackerel, black pomfrets, stomatopods, and cephalopods still experience a decline in stocks. However, the rates of this decline, particularly for stomatopods and cephalopods, are much slower than what they experience under the baseline scenario. Interestingly, the rates of stock and catch decline for Indian mackerel remain the same as the rates under the baseline situation. This is because of the fact that under the optimal scenario, the number of fishing hours by purseienes, the efforts of which are mostly dedicated mackerel, increases quite substantially. This increase in purseseine effort is offset by any reduction in the effort by other vessel classes, for instance, outboard motor boats.

Another interesting finding is that the optimal model results show that there is almost no change in the total value of harvest (Rs.4,969 million) from that of the baseline simulation (Rs.4,929 million). However, there is a substantial reduction in the cost of fishing from the baseline level of Rs.4,844 million to the optimal level of Rs.3,155 million, resulting in a profit of Rs.1,814 million or 36.50 percent of the total market value. This is due to both biological and economic reasons. Biologically, more number of species become sustainable, stable or less unsustainable over the ten-year period under the optimal scenario. This certainly increases the total catch of certain species. Economically, the model allocates more effort toward high value species and high-productivity (or unit cost) vessel. This helps the fishing industry realise higher rent from fishery. Thus, the optimal effort distribution not only increases fishery rent, but also increases the chance of several model species to become either sustainable or more sustainable.

The results of the single species model estimated the sustainable yield and maximum economic yield without considering interactions between stocks, species, gears, labour, processing and marketing factors. On the other hand, the multi-species model presented in this section incorporated the dynamic nature of the fishery and multi-gear technology interaction into a management plan in order to assess biological and economic sustainability. We conducted several simulations of the model. In the baseline model, the endogenous effort level was forced on all the future ten years based on the observed effort level of 1998. This effort restriction enables us to understand the future sustainability of catch and stock given the current effort level. The result of the baseline model shows that stocks of most of the model species are declining over the period. The mackerel, which is one of the most important pelagic species, clearly suffers unsustainability in the future catch and stock if the current effort level is continued.

The above results clearly support the view that the fishing industry in Mangalore spends too much effort and cost to realise their market income. Through optimal re-distribution of its effort, the same market value of fishery output can be obtained at almost 35 percent less cost. For the optimal scenario, the amount of labour payment is estimated at Rs.1,425 million, only a slight increase from the baseline estimate (Rs.1,391 million). Since the wage payment is a fixed portion of the market value of the catch, and the total revenue does not change much, this small increase in the wage is reasonable.

The model captures the dynamic nature of fishery through an inter-temporal stock growth equation. This equation balances the stock in each period to the previous period's stock, plus net growth minus harvest. This gives the model the ability to track the impact that the current fishing effort (technology and capital) has on future sustainability of fish stock. We can also impose a separate sustainability constraint that requires that each year's stock be more than or equal to the last year's stock. Through such a constraint, one can analyse the trade-off between biological sustainability and social welfare impact on the fishing community.

Current fishing intensity in the study area is both biologically unsustainable and economically inefficient. A significant portion of the effort is wasted, a common symptom of the "tragedy of commons" problem. The optimal re-allocation of existing vessel technology could improve this situation by allowing more productive technology like purseseine to intensify their effort. Such reallocation not only increases fishery rent but also make fishery resources biologically more sustainable than what the current industry can do.

Recommendations

Fishery management policies in India are broadly governed by the Indian Fisheries Act of 1897 and the Marine Fisheries (regulation) Acts of the respective states, which were enacted in the eighties. The Karnataka Marine Fisheries (Regulation) Act of 1986 provides for the regulation of fishing through seasonal closure of fishing operations by specified vessels, restriction of fishing in specified areas and control of indiscriminate fishing of brood stock and juveniles through regulating mesh size. In Karnataka, for instance, mechanised fishing vessels are prohibited from fishing during the monsoon season for two to three months. However, most part of the Act has not been implemented due to a lack of information on the impact of such policy measures on different stakeholders. In this section, we calibrate our model to simulate the impacts of various fishery regulation policies, such that the results of the simulation will help to shed light on how the unsustainable harvesting as seen in the baseline or optimal fishery simulations can be corrected. For the purpose of the analysis, we consider two policy scenarios:

Policy Scenario I (Restricting Harvest Technology):

Under this scenario, we analyse the effects of placing restrictions on harvesting technology that reduces the harvesting capacity of purse seines. Under both the baseline and optimal harvesting scenarios, this vessel type is found to promote an unsustainable harvesting of mackerel, one of the commercially important pelagic species. The technology restriction may be implemented by changing the mesh size of nets that are used on this vessel. This policy change represented in the model reduces the effort standardisation parameter for purse seines from the baseline level of 1.0 to 0.7.

Policy Scenario II (Seasonal Restrictions):

For this scenario, a seasonal restriction of two months on all mechanised vessels such as purse seines, trawlers and outboard fishing nets is considered. This policy allows stocks to rejuvenate during the spawning season and directly impacts the total annual effort expended by fishers. Moratorium on harvesting is most common under the Karnataka laws. Therefore, maximum effort constraints are reduced by 2/12 of the baseline levels for the above vessel types.

The alternative management options discussed in the report are only indicative and not exhaustive. The impact of many other options such as restrictions on fishing in different depth zones to protect the interest of the small-scale fishermen could be introduced to enhance the equity aspects. Thus, the introduction of management regulations would improve not only the sustainability of the resources, but also the economic returns from the fishing industry.

The study presents the estimated values of stocks of selected species, gross returns, total cost, net profits and wage payments under Policy Scenarios I and II. The initial stock (actual stock in 1998) allows comparison of the effectiveness of each of the policy options in enhancing stock levels and also economic costs and returns. It is clear that the two policy options have different impacts on individual species. For most of the species, both scenarios will result in much higher stock levels through to the year 2007 than the optimal harvesting scenario discussed earlier, except in the case of species such as stomatopods and cephalopods. It is interesting to note that under the optimal harvesting plan, there is a decrease in the mackerel stock to almost half of the initial stock. However, each of the policy scenarios discussed here show an improvement of the stock. The stock of the oil sardines and stolephorus also improve under both the scenarios.

It could be observed from the results that some speciesthat are unsustainable under the optimal harvesting scenario such as prawns, pomfrets and scads, becomes sustainable under each of the policy scenarios discussed. The sustainability of prawns, one of the most highly targeted species by the trawlers, improves under Scenario II and I. The stock level of scads, which reduced under optimal harvesting strategy to 10,613 tonnes from the initial stock of 13,000 tonnes, increases to 14,799 tonnes under Scenario I, and to 12,843 tonnes under Scenario II.

As expected, the economic returns accruing to fishermen and payment to labour are slightly lower under the subject scenarios. The gross returns diminished from Rs.4.97 billion under the optimal harvest level to Rs.4.21 billion and Rs.4.56 billion under Scenario I and Scenario II, respectively. Similar trends can be observed with respect to labour payment. The total cost of harvesting also slightly decreases from Rs.3.16 billion under optimal harvest levels to Rs.2.93 billion in Scenario II due to the impact of reduced fishing efforts for two months.

Although the two-month moratorium on fishing efforts (Scenario II) improved long-term stock levels of most species considerably, the major species of the Mangalore port such as Indian mackerel, experience a setback in stocks by the end of the simulation period by as much as 25 percent. High value species like cephalopods and stomatopods also lose their stock level significantly. It is clear that the current policy of seasonal restriction of two months is not fully potent in stemming the unsustainability problem of at least some major species.

The optimal simulation is developed without current level effort restrictions. The results of the optimal model reveals declining stock levels of selected model species such as mackerel, cephalopods and stomatopods. The estimated total revenue from both the models are almost same. But the cost of harvesting from the baseline level to optimal level decreases by 54 percent, and hence profitability increases by 21 percent. Thus by promoting the effort combination, the biological and economic sustainability can be improved.

The above results clearly support the view that the fishing industry in Mangalore spends too much effort and cost to realise their market income. Through optimal re-distribution of its effort, the same market value of fishery output can be obtained at almost 35 percent less cost. For the optimal scenario, the amount of labour payment is estimated at Rs. 1,425 million, only a slight increase from the baseline estimate (Rs. 1,391 million). Since the wage payment is a fixed portion of the market value of catch, and the total revenue does not change much, this small increase in the wage is reasonable. Some of the important recommendations of the study are:

- The increase in fishing efforts during 1970s and 1980s led at first to rapid increase of commercial landings, which grew at the rate of 2.6 percent and 5.95 percent until the early 1990s. During the 1990s, there was a negative growth of total production. The legal framework to control the fishing efforts was not enforced for socio-economic reasons.

- In order to study the biological and economic sustainability of the Karnataka fishery, a single species model was constructed to help the fishery management authorities to limit the effort level. The results of the single species model, shows that most of the species are harvested at very close to maximum sustainable yield levels and above the maximum economic yield.

- Multi-species mathematical programming models implemented for – Mangalore port estimate the response of stock and catch levels under various scenarios. The objective function was to maximise the net benefits from a fishery, given a set of constraints. The results of the baseline simulation model with of the 1998 effort level on the next 10 years shows that most of the model species are biologically and economically unsustainable. The policy simulation of effort restriction and seasonal moratorium indicate that these policies do help sustain some species, but fail to protect most popular species like Indian mackerel, and high value species like cephalopods and stomatopods.

- As shown by the results, we cannot expect to get increased catches by simply increasing fishing effort. On the other hand, we can improve the sustainability by changing the exploitation pattern. At present the fisheries exploitation is based on fishing through trawlers of different types. It is possible to achieve important economic and biological benefits by proper re-allocation of fishing efforts and keeping fishing costs at their minimal levels.

- With rebuilding of stocks through increased mesh size, closing areas and seasons for fishing, at least for destructive fishing, the sustainability can be improved.

MAP OF THE STUDY AREA

Economic and Social Management of Estuarine Biodiversity on the West Coast of India

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Introduction

Estuaries are coastal ecosystems that sustain human life in many ways. They provide a variety of livelihood opportunities for rural communities. Fishing, paddy cultivation, traditional prawn cultivation, clam fishing and lime shell collection, salt making, coir fibre making, traditional ferry services, clay and sand mining, etc. were the major occupations of rural communities. Since these activities used traditional technologies to meet their own subsistence needs, local communities could not accumulate wealth to make fresh investments on modern economic activities.

Due to the influence of globalisation, of late, these systems are being intensively exploited by modern industrial enterprises, resulting in the degradation of biological diversity that leads to food insecurity. Although these concerns were discussed at length in many national and international forums, the role played by tropical estuaries to sustain global biodiversity has not been fully recognised for want of sufficient empirical studies on the use and abuses of these ecosystems. In India, very few attempts have been made to study them in detail - to value them, look into the causes and consequences of degradation, particularly the socio-economic issues and management. We wish to overcome these lacunae by making an attempt to understand an estuarine system, which is intensively used by various stakeholders along the western coastal belt of the Indian peninsula.

Objectives

The major objectives of the study are to:

- Characterise the nature of fish and shellfish diversity, and to describe the ecological services of major estuaries along the West Coast of India.
- Estimate the direct, indirect and non-use values of estuarine biodiversity, and to compare the economics of degraded and undisturbed areas in the selected estuaries using appropriate methodology in environmental economics.
- Identify the major causes of biodiversity erosion in these estuaries and document these processes in detail.
- Explore how different stakeholders have enforced their claims on the estuarine environment and to examine the role of various institutions in the development of such rights and economic activities.
- Suggest appropriate socio-economic strategies for the prudent use of estuarine resources and biodiversity.

Methodology

Since estuarine uses are influenced both by natural and socio-economic forces, a multidisciplinary approach is essential to understand the uses and abuses of resources. This study therefore, begins with characterising the fish and shellfish diversity in selected estuaries, and proceeds further to valuation of the ecosystem. Biodiversity of Indian estuaries have been declining over the last few decades due to state interventions and industrialisation that encouraged intensive use of resources and environment. Economists argue that biological diversity degrades due to market failures, institutional failures and policy failures. Since biodiversity, being an environmental good, could not be traded in a formal market, the diversity degrades when markets fail. There are many reasons for this. Failure to internalise externalities, public good features, absence of well-defined property rights, creation of an appropriate structure of property rights are all

[1] *Rice variety*

responsible for this. Therefore, if biodiversity were to be preserved, governments should ensure well-behaved markets by preventing market failures.This study examined the various issues related to markets, government, policy and institutional failures that cumulatively contribute to environmental degradation in estuaries. The study then estimated the economic values - direct, indirect, option, bequest and existence - of estuaries using the popular neo-classical environmental economics taxonomy. Accordingly, the summation of direct, recreational and non-use values would provide the total gross economic value. To simplify the calculations further due to lack of time, only the important traditional and modern activities are included in the present analysis. Activities like fishing, wetland agriculture, prawn filtration, aquaculture, sand mining, navigation and ferry services, etc. have formal markets, and hence their respective values are approximated to the gross revenue produced by the units operating in these activities. Indirect use value of estuaries, especially backwater tourism, is estimated using the **travel cost methodology (TCM)**, and the non-use economic values are estimated using **contingent valuation method (CVM)**. Total economic value of the estuary is then arrived at by summing up the direct, indirect and non-use values. This value is divided by the total geographical area of the estuary to arrive at the per acre value of the estuary as a natural resource. This in fact, is an underestimate, as it has to still account for many other implicit values accruing from the uses of mangroves, minerals etc. It is expected that these estimates, being a first approximation, would be useful for policy formulations involving the use of estuarine ecosystems.

Study Areas

Two estuaries (Cochin estuary in Kerala and Kali estuary in Karnataka) along the Southwest coastal zone of India were selected for this study. **Cochin estuary** of Kerala is one of the largest brackish water bodies in India. It stretches to over 24,000 ha in area and contributes to about 50 percent of the total area of estuaries in the state. **Kali estuary**, on the other hand, is one of the smallest estuaries in the North Kanara district of Karnataka state, situated at 14° 50' 21"N and 14°10'06". The Cochin estuary has been exposed to the influences of international markets and commercialisation of economic activities from an early date. To appreciate the changes experienced by this system and to provide a comparative perspective, the Kali estuary of Karnataka State, which has not been commercially exploited until recently, is selected.

Sources of Data, and Modes of Data Collection

Two types of databases have been used in this enquiry. The first set of data refers to the hydro-biological processes (water quality, composition and diversity of living organisms as well as ecological process), while the second set falls under the economic and social domain of fishing communities, gazni/ pokkali[1] farmers, and households engaged in prawn filtration, sand mining, traditional ferry services, etc. Economic activities are valued using separate sets of questionnaires. In a few instances, secondary data like the Census reports, administrative reports and village/panchayat reports have also been used. The modern stakeholders are identified as the Cochin Port, those involved in modern aquaculture, navigation and tourism activities.

Major Results

Causes of Degradation

The study revealed a high growth of Industrial pollution, sediment accumulation, dredging, construction activities and reclamation in Cochin estuary, affecting fishing activities, agriculture, water transport and trade.

Decline in Fish and Shellfish Species Diversity

One of the major emphases was to characterise fish and shellfish diversity in estuaries, and to describe their ecological services. 73 finfishes and eight shellfishes were recorded during 2001-2002 in Cochin estuary, while 63 finfishes and nine shellfishes were reported in Kali estuary. The lowest specie diversity was recorded in Fort Kochi bar mouth region due to specialised use of Chinese nets. The northern bar mouth region on the other hand, recorded species availability between 61 and 68. High species diversity was recorded in the southern side of the medium saline zone (ranging between 68 and 71), while the diversity recorded along the northern side of the medium saline zone varied between 26 and 53. In the fresh water zone, on the other hand, the species diversity varied between 68 and 70. Comparing different zones in Cochin estuary, we found that diversity is higher in the southern side of the medium saline zone, followed by the fresh water zone, the northern part of the medium saline zone, northern bar mouth station, and finally the Cochin bar mouth station. Comparing these estimates with previous studies, we noticed a definite reduction in the availability of estuarine fishes in Cochin estuary.Previous researchers had listed 150 fish species belonging to 100 genera under 56 families from this estuary during the early 1980s. From this comparison, it appears that a large number of species, especially finfishes from Cochin estuary vanished during the last 20 years, although it would still be difficult to pinpoint them due to the methodological differences between the study undertaken by our team and earlier studies. However, the fact that large numbers of species have vanished warrants our concern.

Decline in the Catches and Value of Fisher

The lowest level of production is recorded in Zone II B, which is badly affected by the effluents and waste emissions of the modern manufacturing industries. The average level of estuarine fish production in the Cochin estuary is estimated as 4,300 Kg/ha, while the lowest productivity (288 kg/ha) is recorded in Zone II B. The medium saline zone (Zone II A) recorded the highest yield of 2,773 kg/ha, followed by the Munambam bar mouth region (2,761 kg/ha), fresh water zone (Zone I) with 1,169 kg/ha and Cochin bar mouth with 642 kg /ha.

Paddy Production in Pokkali Fields

The total production during the year is estimated to be 6,568.5 tonnes. The annual production of pokkali paddy in Zone II B is 2,168.6 tonnes (33.02%), followed by Zone I with 2,094.7 tonnes (31.89%), 9,876.856 tonnes (30.07%), Zone II A with 1,773.05 tonnes (26.99%), Zone III B with 350.17 (5.33 %) and Zone III A with 182.01 tonnes (2.77%).The productivity in this zone (977.30 kg/ha) exceeded the overall average wetland paddy productivity (854.5 kg/ha). This shows that no clear proof exists to indicate that traditional wetland paddy cultivation is affected by biodiversity degradation, especially in areas that are highly polluted. This may be attributed to the active presence of traditional institutions and agrarian organisations in this region.

Gross Values of Major Activities

The total gross direct value generated by both the traditional and modern stakeholders from Cochin estuary for the year 2001-02 is Rs. 409.85 crores. Around 77 percent of this is the contribution of modern stakeholders**.** Estuarine capture fisheries contributed around 22 percent, while agriculture contributed only one percent. The available evidence indicates that the pokkali paddy farming fields are being converted to modern aquaculture, although there is local resistance towards such commercialisation. Since no institutional arrangements exist to negotiate an arrangement beneficial to both traditional and modern stakeholders and the environment, modern development activities are likely to ruin the ecosystem and the people alike.

Local Institutional Arrangements

The process of resource sharing and the economic organisation of various production processes had been influenced by local perceptions about ecosystem services and functions, and are internalised in traditional social institutions. The traditional common property institutions regulated fishing activities, the ***padashekara committees*** that supervised crop rotation in wetlands and the institution of ***kalakkippidutham*** regulated labor allocations and circulation. Rights over fishing grounds/ territories were enforced by respective gear groups by defining territorial boundaries and rules for fixing nets within such defined territories during the process of fishing. The respective gear groups excluded outsiders from these territories while involved in the activity of fishing, and these territories remained open to all other stakeholders as soon as they finished fishing. The agrarian communities organised their activities through "***padashekarams",*** local organisations of peasants to initiate collective action. These organisations reduced risks and uncertainties, minimised transaction costs, legitimised labour recruitment and supervised crop rotation in saline wetlands. The ***Padashekarams*** also controlled the socio-political life in many villages. These arrangements stand out clearly as social arrangements for ecological and socio-economic sustainability of estuaries. Although the traditional economies appeared to be equitable and sustainable, they could not generate enough economic surpluses to undertake any substantial investment for development.

State Failures

The study revealed that the state has failed to recognise the role of traditional coastal zone institutions/organisations in the control of resources and estuarine environment. Modern institutions did not perform either. Although there exist a variety of formal rules for regulating estuarine activities (fisheries, agriculture, aquaculture, water quality and pollution, biodiversity protection, reclamation, dredging, resource ownership, movement of cargo and trade), these policies are scattered, and hence the government does not have a holistic vision for crafting policies for estuarine governance.

Policy Recommendations

This study suggests both immediate and long run measures to slow down, if not stop, the process of degradation in Indian estuaries.

Short Run Policy Measures

- The Cochin Port Trust should explore the possibility of developing markets for dredged materials by introducing appropriate economic incentives and fasten measures to internalise the ecological and social costs of dredging activities.

- The government has to adopt a differential policy for allowing reclamation that supports livelihood of traditional estuarine communities, and implement it immediately through local bodies (grampanchayats). At the same time, the government should discourage large-scale reclamation by modern enterprises through legal or economic instruments, and integrate the initiatives of various government departments and agencies through district panchayats.

- Steps may be taken by the Kerala State Pollution Control Board to mitigate industrial pollution using environmental economic principles. The Board should develop, implement and monitor concrete action plans for mitigating brackish water pollution with the participation of various stakeholders and local bodies.

- Immediate measures should be taken by the concerned departments (Public Works Department of the State/Central Government, Greater Cochin Development Authority (GCDA), Goshree Island Development Authority (GIDA), etc) to remove barriers obstructing the tidal functions of estuaries.

Long Run Policy Measures

Evolving a National Policy on Estuaries

The Ministry of Environment and Forests should draft a comprehensive "estuarine development and management policy" to ensure equitable and sustainable use of estuarine resources and environment. The proposed policy document should indicate the rights and responsibilities of the Central, State, local Self-Governments and other local stakeholders in the use of estuarine resources and environment.

Empowering Local Institutions for Governance

Once the shift in the approach towards governance is established through the policy declaration, the state has to initiate a process to empower local communities, local self-governments, informal institutions and organisations to undertake the task of resource management. Structural reforms, including enactment of legal codes and informal codes of conducts, are therefore required at the grassroot level.

Enacting Legislation

The Government of Kerala State should enact legislation to empower local grampanchayats as nodal agencies responsible for the control and management of estuarine resources and environment.

Co-management of Estuaries

The state has to ensure the participation of local stakeholders in the management and governance of estuaries. We have already indicated that the partnership between the public and private stakeholders could deliver an outcome that is acceptable to various parties, and environmental economic approaches are helpful in deriving such arrangements of good governance

Traditional Knowledge Systems and Institutions

Traditional coastal zone/estuarine institutions have to be studied in detail, and indigenous knowledge systems have to be properly integrated for the better governance of estuarine systems in India.

Environmental Movements

The State should view public resistance and agitation against environmental degradation in the proper spirit, and attempt to integrate these feelings into environmental policies. Oppression of social and environmental movements brings more harms than good.

Conclusion

The limitations of this approach are also obvious. As repeatedly claimed in this study, valuation of environment supported by the appropriate institutional and organisational arrangements can only resolve the evolving crisis of the estuarine economies. The state has to accept and learn from the experiences of traditional coastal zone institutions. Moreover, it has to initiate the crafting of appropriate modern institutions, if necessary, for the better governance of these ecosystems. The collective action necessary for the healthy co-existence of various stakeholders can only be generated through this process. This study is only a beginning to convey this message.

Environmental Economic Analysis of Inshore Fishery Resource Utilization of Coastal Kerala

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Introduction

The coastal zone, which is an interface between land and ocean, has enormous socio-economic importance, as these areas are characterised by an abundance of natural resources. The coastal belt of Kerala, about 590 kms long, has 226 marine fish landing centres and an equal number of fishing villages with high population density. The coastal habitat is under severe threat due to human intervention in the forms of excessive fishing in the inshore waters, shallow water mining, lifting of coastal sands, destruction of mangroves, inflow of pollutants, growing urbanisation, construction of sea walls and other related activities. These activities are bound to disturb the coastal ecosystem, affecting the sustainability of fishery resources and livelihood security of the vast majority of inhabitants. Besides, the technological advancements in fishing methods, coupled with increasing export demand for fish, lead to over-crowding of fishing units, especially during peak seasons. This condition affects the very sustainability of ecosystems and increases the need for environmental quality and conservation of resources.

Objectives

The specific objectives of the present study are to:

- Examine and document the extent of recent changes in the techno-exploitation pattern of inshore open access marine fisheries and socio-economic condition of stakeholders.
- Assess the economic impact of such changes on structure, composition and productivity of inshore marine fisheries and the livelihood security of the coastal population.
- Evaluate the economics of operation of different fishing units and their impact on fishery resource conservation, and to suggest policy measures for sustainable development of the coastal zone.
- Estimate the economic loss due to the environmental degradation of inshore marine ecosystems, and to provide sufficient socio-economic indicators to administrators and policy makers for decision-making in regional environmental planning.

Site

A preliminary survey was conducted in all the fishing villages covering the entire study area from Poovar in the south to Munambam in the north along the southern Kerala coast to identify representative sample villages of mechanised, motorised and non-mechanised fishing centres. The villages and landing centres were selected for detailed study on the basis of use patterns of marine coastal resources and intensity of operation of different craft-gear combinations, both in artisanal and mechanised sectors of Southern Kerala. (Fig. 1)

Fig.1 Map showing selected centres for the study in Southern Kerala

Methodology

The villages were classified into highly degraded, moderately degraded and comparatively undisturbed categories in relation to the intensity of environmental pollution as well as fishing. The costs and earnings data for all types of fishing units were collected on sample days from each landing centre, and the economics of different fishing units were evaluated, covering all seasons in a year (2001-2002). The socio-economic survey was conducted in all selected centres to analyse the socio-economic framework of the coastal rural sector. Secondary time series data from 1962 to 2000, relating to species-wise catch was obtained from the National Marine Living Resources Data Centre of CMFRI. It was used to study the extent of variation in catch composition, production trend of inshore marine fisheries and the impact of technological advances on marine resource base. In order to evaluate the response of those involved in fishing and allied activities regarding environmental and conservation problems of natural fishery resources, an opinion survey was also conducted in all the selected villages.

The sample centres selected for detailed study were Munambam, Cochin, Alappad Neendakara and Kochuveli for the highly degraded category; Arthungal, Valanjavazhi, Thangassery and Vizhinjam for the moderately degraded category; and Kattoor and Poovar for the comparatively undisturbed category. Among the selected centres under the highly degraded category, Munambam, Cochin and Neendakara were predominantly mechanised fishing centres having serious environmental and conservation problems. The major environmental concerns of these centres were excessive fishing pressure on the inshore region, heavy destruction of the bottom fauna, juvenile fishing, by-catches, discards and coastal pollution. Another highly degraded area covered under the study was Kochuveli village in Thiruvananthapuram District, where a large industrial unit producing titanium products is situated. Large quantities of acid wastes from this industry flow into the sea, which causes many health hazards. Some centres under the study area were considered degraded due to sea erosion and sand mining. Alappad village in Kollam district was one of the most affected and degraded villages due to the invasion of the furious sea, especially during the monsoon season.

In the moderately degraded areas, the proliferation of motorised gears, operating within the near shore areas create heavy threat to the habitat. The indiscriminate operation of a large number of mini trawl and ring seine units, operating from the landing centre at Valanjavazhi and Pallana, led to the depletion of some species of fish of commercial value and importance. The predominant use of gears with reduced mesh size leads to juvenile fishing, and thereby over fishing of many important species of fish. A large proportion of the catch in mini trawl units is composed of juveniles/sub-adults of the flatfish Cynoglossus macrostomus and shrimp Parapenaeopsis stylifera, causing damage to recruitment. Oil spills from outboard engines in the bay-landing centres such as Thangassery and Vizhinjam led pollution in the near shore waters.

The Kattoor coast of Alappuzha and Poovar in Thiruvananthapuram district are comparatively undisturbed areas. Kattoor is a natural landing centre with motorised and non-mechanised units under operation. Most of the gears under operation in Poovar are non-mechanised units, such as Catamarans (Plank built canoe), shore seine units and motorised plywood boat with gill net/ hooks and line.

The extent of damage caused by technological advancements, and thereby destructive fishing by the mechanised as well as the motorised sectors was analysed. The economic loss due to juvenile fishing by different fishing units was estimated using suitable models developed during the study. Cobb-Douglas production function was used to evaluate the economic efficiency of input utilisation in trawler operation in three different regions. The Net Present Value (NPV) was calculated for discounted economic loss due to various environmental factors.

Results and Findings

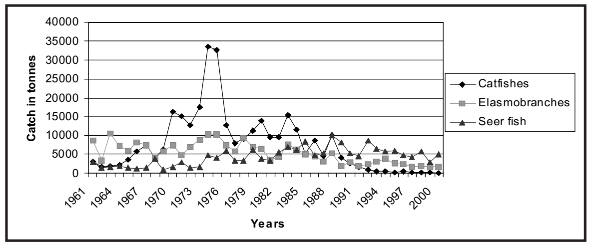
Fish landings

The analysis of species-wise annual landings of Kerala during the last four decades clearly indicates that the effect of technological changes in fishing methods such as introduction of mechanisation and motorization of country crafts had affected some of the marine resources, leading to their depletion. The catfish fishery along the Kerala coast is the best example of the depletion of a resource due to indiscriminate fishing by the mechanised sector. The average annual catch of cat fish in 1961 was 3,114 t, which rose upto 33,526 t in 1974 owing to the large-scale exploitation by the mechanised trawlers and purse seiners. During the intensive mechanisation period, this came down to only 103 tonnes in 2000 (Fig. 2) .The major reason for the decline of this particular species was the over fishing of brooders by the mechanized purse seiners and trawlers.

The pelagic fish, such as the carangids, tunnies and seer fish were exploited maximum between 1985 to 1990, mostly by the motorised country crafts, especially using ring seines, gill nets and hooks and line. From then on, the catch showed a declining trend in spite of the increase in the number of motorised units in the area. Another endangered species is the polynemids, collectively called threadfins. The major cause of their depletion was the destruction of their nursery grounds by mechanised trawlers. The annual production of elasmobranches was also shown to be declining ever since their peak landings of 10,338 t in 1974, which was reduced to only 2,832 t.in 2000 (Fig.2). The heavy exploitation of sharks by the mechanised vessels along the coast reduced the catch from 7,747 t in 1983 to 1,706 t in 2000.

Certain less priced fish such as threadfin breams, lizard fish and ribbonfish considered by-catches in the mechanised trawlers, recorded an increasing trend in their catch. It was estimated that, in the total trawl landings, more than 45 percent was composed of by-catches, which included other than the above mentioned species, the juveniles and sub-adults of a wide variety of commercially important fish. The increase in the landings of the cephalopods, mainly an export item, was also noticeable in recent years.

Fig.2: Catch Trend of Cat fish, Elasmobranches and Seer fish



Socio-economics of Fishing Communities

The selected villages along the coastal stretch of Kerala between Munambam and Poovar were surveyed to assess the socio-economic status of the fishermen and the other people depending on the coastal resources for their livelihood. The total number of households ranged from about 1,000 in Kochuveli to 12,000 in Thangassery. In each village, the coastal wards, predominantly inhabited by fishermen, were covered under the survey and information was collected on socio-economic indicators such as housing pattern, family size and demographic features, literacy level, ownership of fishing equipment and employment pattern with special emphasis on fishing people, income distribution, consumption and expenditure pattern and indebtedness.

Regarding the ownership of fishing implements, the non-mechanised fishing vessel owners were more in Kochuveli and Poovar where 18 and 20 percent of the families respectively had non-mechanised catamarans with gill nets. The percentage of families having non-mechanised shore seine were 7 percent in Poovar and 4 percent in Kochuveli. In Alappad and Kattoor, 5 percent of the families were the owners of non-mechanised dinghies with gill nets. In Kochuveli, the livelihood of the fishing community was seriously affected by pollution, which was indicated by the non-existence of any improved technology in this area. Fishermen mostly used country craft and catamarans without any sort of mechanised device. In Poovar, more families were operating non-motorised catamarans and country crafts, mainly because it was an economically backward village having no facility for institutional credit. In Vizhinjam, 23 percent of the families were owneroperators of plywood boat units with gillnet/hooks and line. Motorised mini trawl units were found more in Valanjavazhi with 24 percent of the families owning them. The households that owned mechanised trawlers were 5, 4 and 4 percent in Alappad, Neendakara and Munambam respectively.

Table 1: Ownership Pattern of Fishing Implements – Percentage Distribution of Families

Village	Non-mechanised			Motorised			Mechanised
	Shore seine	Catamaran & gillnet	Dinghy & gillnet	Plywood boat & gillnet	Ring seine unit	Mini trawl unit	Trawler
Poovar	7	18	-	8	-	-	-
Vizhinjam	-	3	-	23	-	-	-
Kochuveli	4	20		2	-	-	-
Thangassery	-	-	-	7		2	-
Neendakara	-	-	-	4	-	-	4
Alappad	-	-	5	6	4	-	5
Valanjavazhi	-	-	-	-	-	24	-
Kattoor	-	-	5	-	3	4	-
Arthungal	-	-	2	-	1	12	-

Out of the total, 69 percent of the adult population in Arthungal was employed, followed by Poovar (67%) and Valanjavazhi (61%). The lowest level of employment was in Kochuveli (47%), followed by Thangassery (51%), where most of the women were housewives. About 50 percent of the employed population in Vizhinjam, Valanjavazhi and Kattoor were wage earners in the motorised fishing units, which provided better income to fishermen. About 47 percent in Neendakara and 48 percent in Munambam were employed as wage earners in the mechanised fishing units. Only 21 percent of the people in Kochuveli and 19 percent in Poovar were engaged in fish marketing, mostly representing the women head load vendors, generating additional income to support their families. In Kochuveli, because of the discharge of effluents from the titanium factory into the sea, the intensity of fishing had come down, causing detrimental effect on the fishery. There had been a considerable shift in occupation from fishery to non-fishery activities. Many had migrated to other places for employment. About 28 percent in Valanjavazhi were engaged in processing work, mostly ladies working in shrimp peeling sheds.

On the whole, in all the villages, the expenditure pattern indicated that about 80 percent of the household expenditure was for consumption purposes. The average annual household expenditure ranged from Rs.19, 600 for the families of shrimp peeling workers in Kattoor, to Rs. 65,412 for the mechanised boat owning families in Munambam. . However, it was observed that medical expenses of families in different villages had no significant relation with the intensity or incidence of pollution. The credit utilization pattern clearly indicated that in most villages, maximum loan was availed for productive purposes.

Costs & Earnings

In the mechanised sector, the annual net profit from the trawlers having an Overall Length (OAL) of 36-42ft, 45-48ft and >50ft operating from Cochin Fisheries Harbour during 2001-2002, worked out to Rs.3.66 lakh, Rs.6.98 lakh and Rs.4.14 lakh. About 40 percent of the total expenditure was for fuel, followed by 25 percent for wages. Regarding the purse seine units, the annual net profit worked out at Rs.14.36 lakh, and was maximum for the above 50ft craft category, with the highest rate of return of 87 percent. The average revenue obtained for the mechanized gill net units was Rs.20.87 lakh, with a net profit of Rs.4.69 lakh.

The annual profit for the operation of the ring seine units with a craft of >50ft at Valanjavazhi was Rs.3.75 lakh. The major expenditure was labour charges (40%) as crews of 20-30 people, depending on the size of the craft, were engaged in a single day trip. The annual net profit obtained from a motorized mini trawl unit during the above period was Rs.1.48 lakh at Valanjavazhi and Rs.0.93 lakh at Arthungal, with the highest rate of return of 168 percent for the former landing centre. The average annual revenue from a plywood boat with gill net, operating from Vizhinjam centre was Rs.5.73 lakh with a net profit of Rs.0.77 lakh, and the net profit from the same type of unit at Thangassery centre was calculated at Rs.1.11 lakh.

Comparatively higher rates of return were obtained from the non-mechanised units, such as catamaran and shore seine units, mainly because of lower investment. The only exception was the non-mechanised dinghy with gill net, for which the rate of return was only 19 percent. The net profit from a shore seine unit worked out at Rs.1.14 lakh at Poovar and Rs.0.90 lakh at Kochuveli, with a rate of return of 126 percent and 103 percent respectively, and 95 percent of the expenses were towards labour costs. At Kochuveli, due to pollution, the average catch per unit of catamaran was much less than that of Poovar, but the average revenue was high because fishing was extended to interior ground, therefore they could get quality fish fetching higher prices.

The key economic indicators of operations of all types of fishing units were calculated and compared. Among the mechanised units, the average catch per day of operation was highest for trawlers, and the lowest was for gill net, but in terms of value realisation, it was *vice-versa.* Labour productivity was more in trawlers. Among motorised units, the catch and revenue per day of operation was highest in ring seine. Average revenue realisation was high in mini trawl due to the landings of penaeid prawns. Labour productivity and the rate of return were also found to be higher in mini trawl units. Among non-mechanised units, shore seines obtained the highest catch per day of operation. Quantity of fish produced per man, per day in shore seine was very low indicating high labour involvement in its operation.

Production Function Model

The production function analysis using Cobb-Douglas model indicates that there is scope to enhance the net profit of trawlers by increasing fishing days and the area of operation at Neendakara and Munambam, whereas at Cochin Fisheries Harbour, it is almost at the optimum level. At Neendakara landing centre, fishing days in a year can be increased from the average level of 193 to 204, and in Munambam from 203 to 229 days, to get the maximum profit. Even though the number of days fished in a year are not upto the optimum in all the major centres, it was observed that there was still excessive fishing pressure due to over crowding of fishing units.

Economic Loss due to Juvenile Fishing

The economic loss due to juvenile fishing by different fishing units was estimated using the model developed on the basis of the quantity of juveniles landed by different gears, price level of juveniles and adult fish of each species, and the approximate period of juveniles to attain adult or marketable size. Even though the annual revenue generated by a purse seiner is Rs.20.7 lakh, the annual economic loss due to juvenile fishing by the same unit works out to Rs.39.6 lakh. In the mechanised trawler, the economic loss due to juvenile fishing was Rs.28.3 lakh as against its gross annual revenue of Rs.31.2 lakh. In the motorised sector, a ring seine contributes a loss of Rs.19.1 lakh, which is higher than that of the annual revenue generated by the same unit (Rs.12.4 lakh), and for the mini trawl, the annual economic loss was estimated at Rs.6.9 lakh. Among different centres, the highest economic loss was at Neendakara harbour with Rs. 239.1 crores/year, followed by Cochin Fisheries Harbour and Munambam. As a whole, the economic loss due to juvenile fishing in the study area alone is estimated at Rs.600 crores per annum, in which the highly degraded centres contribute about 82 percent.

Economic Loss due to Pollution

Environmental problems at Kochuveli and Alappad were discussed in detail, and their effects on fisheries of the area were worked out in terms of Net Present Value (NPV) of loss of fishing income due to pollution for the next 15 years, discounted to the present level. At Kochuveli, because of the pollution problem, people are reluctant to adopt improved technologies of fishing. Due to this, the fishing intensity also has come down. Taking into account the major factors influencing the level of effort and the catch and value, the Net Present Value of estimated loss to the village due to pollution for the next 15 years comes to around Rs. 23.7 crores. Since there can be a flow of future benefits in coming years, a cost benefit analysis is done and the NPV is calculated for 15 years with a discount rate of 12 percent. NPV calculated for Kochuveli is Rs.157.4 crores. The low level of annual landings from Alappad landing centre is mainly due to the sand mining and sea erosion, resulting in the construction of a sea wall, which obstructs the landing centre facilities. The annual economic loss due to these factors amounts to Rs.97.4 crores. The economic loss in terms of Net Present Value calculated for 15 years is Rs. 647 crores.

Loss due to Over-Fishing

Economic loss due to the extinction of some of the species of fish because of over-exploitation was worked out. The net loss due to over-fishing was estimated in terms of Net Present Value of MSY for 30 years, discounted to the present level, which was Rs.160.6 crores for catfish, Rs.458.5 crores for elasmobranches and Rs. 3.9 crores for goatfish. An additional loss of 30 percent of this amount comes in the form of consumer surplus.

Opinion Survey

An opinion survey was conducted on government policies on the conservation of resources, covering 100 people in each of the selected villages, who in one way or other are involved in fishing activities, either as fish workers, fish traders or boat owners. The survey reveals that more than 80 percent of the respondents are aware of the importance of environmental management for the conservation of natural resources, especially fishery. Many of the respondents in the degraded area believed that many economically important species of fish have disappeared or declined from that area, especially from Kochuveli. About 60 percent of the interviewed people at Alappad demanded the construction of a sea wall to protect the shore, and 100 percent to stop sand mining. All the respondents, except those involved in the operation of mini trawl, consider this net as highly destructive and detrimental to the growth of fishery in the long run. However, most of the fishermen interviewed were very cautious in making any response to the restrictive measures, which would affect their present benefits. A majority are in favour of a fishing holiday, but there is no unanimity in the type of unit or duration.

Recommendations

Policy measures have been recommended for the conservation of resources and environmental problems along the study area.

- In Kochuveli, where environmental problems affect the future benefit from fishery, it is suggested that the industrial effluents should be treated before discharging them into the sea through a buried tunnel.
- To prevent the indiscriminate exploitation of fishery resources, there should be fishing holidays for all types of mechanised fishing units and their socio-economic impact should be properly assessed.
- Since mini trawl is comparatively highly profitable and less capital intensive, there is every chance for its expansion. But, it is detrimental to the sustainable development of the fishery. Hence, further proliferation of this unit should be restricted.
- As the economic loss due to juvenile fishing is substantial, the standardised mesh size regulations should be introduced and implemented with proper monitoring for all types of gears in order to avoid juvenile fishing.
- All types of construction along the seashore, even those for developmental purposes, should be regulated, and the CRZ Act should be strictly enforced for the environmental protection of the coastal area
- Due to the economic loss due to the extinction of three species - elasmobranches, catfish and goatfish because of intensive over-fishing, other endangered species such as carangids, seer fish, threadfins, etc. have to be protected by restricting indiscriminate fishing by mechanised as well as motorised fishing units.
- Integration of coastal mariculture with small-scale inshore fisheries issuggested as a viable alternative to enhance the earnings and livelihood security of coastal fisherfolk without endangering the environment.

Conflicts of Water and Soil Resources over Aquaculture Production in Tamil Nadu and Pondicherry

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Introduction

Marine product exports from India depend heavily on the availability of shrimp as it commands a high unit value combined with heavy worldwide demand. The decline in the natural fishery stock has developed the potential of aquaculture to meet the challenges of food security and generate employment and foreign exchange. This has led to the rapid expansion of this sector, which has grown at an average annual rate of almost 10 percent since 1984, compared with 3 percent for livestock meat and 1.6 percent for capture fisheries production. However, the inexorable expansion of shrimp farming generated by market demand, short term gain and government support because of export earnings, has brought with it super–intensive systems, nomadic farmers, environmental and sociological disputes, water quality and disease problems resulting in a decline in shrimp production. All of these appear to be threatening the long-term sustainability of what has undoubtedly become the world's fastest growing aquaculture industry.

A major portion of the conflicts arising from this expansion of shrimp farming is the result of environmental and social degradation that is not included in the costs of shrimp production, where the industry assumes no responsibility for damages to other groups arising from its activities. Mangrove destruction, flooding of crops, salinisation or pollution of land and water associated with the expansion of shrimp farming altogether form degrading factors that affect the surrounding population are dependent on these resources. Further, abstraction of the freshwater from underground aquifers and release of saline water due to semi-intensive shrimp farming are some of the major issues against shrimp culture that seem hardly justified in either the social or economic terms. The impetus given to shrimp aquaculture is mainly due to its lucrative foreign exchange earning capacity. These are the important conflicts that have emerged with the aquaculture industry in Tamil Nadu.

Though the development of the aquaculture industry along the coastal regions of Tamil Nadu and Pondicherry appears to be booming due to a tremendous increase in the revenue of India, environmental degradation due to pollutants from the industry has been recognised to be controversial by environmentalists. If not properly planned, the spread of brackish water shrimp culture into other user area will lead to adverse effects on natural habitats and social customs. Therefore, it is essential to assess and evaluate the environmental impact of shrimp culture resulting in conflicts since it causes unprecedented pressure on natural resources such as water and soil, so that a sustainable aquaculture industry with increased production can be met for the future generations. The major goal of society should be to stimulate production and consumption that do not diminish the capacity of life-support systems to recover after disturbance, which remains within the carrying capacity of the supporting eco-systems.

Status of Shrimp Culture

- Shrimp culture in India is synonymous with coastal aquaculture.
- It stands for export-oriented aquaculture.
- About 1,94,000 ha are under shrimp culture, producing about 1,27,170 MT of shrimps.
- Aquaculture shrimp production today contributes substantially to shrimp exports – 74,826 MT by weight and Rs. 3, 545 crores by value.

Objectives

The objectives of the study are to:

- Evaluate the environmental impacts of aquaculture farms in Tamil Nadu and Pondicherry in the Bay of Bengal region.
- Find out the impact on groundwater and surface water and measure the environmental cost of water salination.
- Calculate the economic benefits of aquaculture in Tamil Nadu and Pondicherry.
- Analyse the degradation/encroachment of agricultural lands and mangroves.
- Value soil degradation of coastal land nearer aquaculture farms.
- Suggest policy measures for sustainable aquaculture in India.

Methodology

A survey-based method is used to assess the socio-economic implications in the following four zones covering Tamil Nadu and Pondicherry.

Zone 1 - Chennai, Ponneri, Minjur, Kancheepuram

Zone 2 - Pondicherry, Cuddalore, Parangipettai, Chidambaram

Zone 3 - Nagapattinam, Sirkazhi, Vedaranyam, Thanjavur

Zone 4 - Pattukottai, Thondi, Mimisal, Ramnad

Hedonic pricing method analysis was carried out based on land evaluation and cost of decay. Contingent valuation analysis was done based on pollution abatement and willingness to pay for pollution abatement.

Sampling was carried out at 3 levels

- Prawn cultivators and owners.
- Farm agriculturists and landowners nearer to aquafarms.
- Workers in aquaculture.

This analysed the socio economic benefits, effects on living standards, consumption patterns, employment and standard of living conditions. The hedonic price version was used to predict the changes in the prices of extent measurement by the increases in values and depletion measured by increase in values. Information was collected from agriculturists and aqua culturists using a land survey and through questionnaires distributed to them by the project researchers. Soil and water samples were collected from problematic zones at the respective areas and analysed for their impact.

Impact of Aqua Effluents

The release of effluents is rich in organic matter and results in siltation, changes in productivity and community structure of benthic organisms. The creeks and canals receiving the discharge also get silted up as a result of organic matter discharged from shrimp farms, which leads to the depletion of dissolved oxygen levels in the receiving waters. Further, the discharge of nutrients carries the risk of eutrophication, and the sudden outburst of algal blooms in coastal waters affecting the environmental conditions and ecology of the area. It is to be pointed out here that even though the disease outbreaks are directly linked to environmental factors, no conclusive study is available to understand the pathways of disease-causing pathogens and the interactions involved. Another prevailing environmental issue is that the fertilisers and bio-pesticides applied in aqua farms also degrade the soil quality, according to the opposition groups. However, it was found that the main chemicals used in aquaculture are lime and chlorine. There is so far, no scientific evidence to show that these two chemicals will lead to irreversible soil degradation. It is therefore wrong to say that shrimp culture is a short-lived industry. The aqua farmers in India largely practice extensive farming, and there is therefore no need to apply a large quantity of lime and chlorine as is the case in Thailand and Taiwan. Unlike toxic pesticides used in agriculture, aquaculture does not involve usage of such concentrated chemicals, except use of medicines / antibiotics and probiotics to ensure the steady growth of the shrimps, and to prevent diseases and mortality in intensive culture systems. In the preliminary stages of aqua farming, chemical components such as lime and zeolite are used as disinfectants and to maintain the alkalinity and fertility of the soil and water.

Impact of Aquaculture on Water Quality

The salinisation of surface water from shrimp farms to the receiving waters also impacts water quality. Shrimp farming causes dispersion of salt into the land around the shrimp farms, thereby increasing the salinity intrusion affecting the paddy fields and other plantations. The soil salinisation further results in devaluation of marginal agricultural land. Abstraction of fresh water from underground aquifers for intensive shrimp farming has also resulted in saltwater intrusion and salinisation of fresh water aquifers. While fresh water aquaculture poses little negative impact on ground water and aquifers, brackish water aquaculture is detrimental to subterranean water resources. This issue concerns the proper site selection and engineering rather than negative aspects of aquaculture.

An investigation on water quality has been carried out in 14 villages in the coastal areas (Sirkazhi Taluk) of Nagapattinam district. Out of 14 villages, eight were found near shrimp culture ponds, viz. Thirumullaivasal, Thazhanthondi, Radhanallur, Vazhuthalakudi, Thirunagari, Thirukovalur, Annappanpettai and Konaiampattinam. Another five villages were found in agricultural areas, viz. Amaipallam, Vadakal, Thirukarukavur, Keeranallur and Semmangudi. Water samples were collected on monthly intervals and analysed for physico-chemical parameters to find out the quality and suitability for drinking purposes. Drinking water samples from Thazhanthondi, Vazhuthalakudi, Varusapathu and Thirukarukavur were found to be safe for human consumption. There is no substantial amount of data regarding water quality in this particular area for pervious years to compare the quality. These findings clearly indicate that shrimp farms have not salinated their neighbourhood as claimed by the anti-aquaculturists.

Impact on Soil

Soil samples were collected from the agricultural / non-agricultural areas close at the aqua farms at varying distances (1km, 3 km, 5 km) to determine the impact on soil quality. Based on the analytical data, it could be inferred that among the 42 soil samples collected in the 4 zones, certain areas (10 samples) in Nagai district and Ramnad district (2 samples) were found to be slightly influenced by the shrimp farms with increased pH (8.4 – 9.9), tending towards alkaline soil and increased electric conductivity values (4.7 –30.0), which depicts the increase in the salinity of the soil. However, no other changes were noted in the soil quality. Most of the sample soils were under paddy cultivation. The impact on the water quality also shows a slight change in the pH (8.3) in the Kurichi area of Nagai district (1 sample) and slightly increased EC values in Minjur (Kancheepuram district) (3.0) (1 sample) and Nagai district (3.0 – 7.6) (12 samples). Other chemical components are found to be within the permissible limits. Based on this environmental analysis, it could be confirmed that shrimp culture activities may result in slight disturbances in areas at the vicinity of the shrimp farms (1–3 km), whereas areas away from the farms (5 km) are less affected.

It was also found that many aqua farms in Nagai and Ramnad districts were situated in the coastal areas close to the sea or backwater areas. Even in areas where there are no shrimp farms, the lands and ground water are saline because of the nearness of the sea and regular tidal flushing, seepage, humid climate, and meagre and narrow fresh water tables in the coastal belt. The normal soil texture appears to be sandy loamy soil with saline patches on the surface layers, which attributes to the coastal salinity from seawater intrusion. Therefore, it is not correct to say that shrimp culture is the only causative factor for soil salinisation or water contamination in these areas.

The only problem identified by our survey is that the shrimp farmers directly discard wastewater without treatment into the public canal, coastal area or rivers and inshore areas, which results in conflicts. If the effluents from aqua farms are treated before reaching the environment, particularly when the organic load is high at the time of harvest, and such effluents are passed through primary sedimentation and secondary biological oxidation treatment before discharging them into the water bodies, there may be an amicable solution for the development of the industry.

Degradation of Mangroves from Aquaculture

The loss of mangroves on account of shrimp culture is diminishing because of regulations imposed by the government. It is also recognised that shrimp farms on mangrove land often support profitable shrimp culture for only short periods of time. In other words, mangroves are not normally the places for sustainable shrimp farming. The acid sulphate soils common in mangroves can also affect the sustainability adversely.

Degradation / Encroachment of Lands

Shrimp culture in Tamil Nadu was introduced with the full support of the State Government as a viable alternative to paddy cultivation, and also for utilising the barren and uncultivable alkaline lands profitably. The area occupied by shrimp / prawn farms in the taluks of Sirkali, Tharangampadi and Nagapattinam is about 2,000 ha, less than 2 percent of the total geographical area. These farms have actually paved the way for the utilisation of the barren, uncultivable lands. This area is situated at the tail end of the River Cauvery irrigation system, and the prospects of cropping have been dim and disappointing due to inadequate and untimely water supply. Hence, the farmers were frantically looking for an alternative use of their lands or for disposing them off for good prices. Due to shrimp farming, the value of land has increased manifold. Before the commencement of shrimp farming, the land value was only about Rs.18,000 to Rs.20,000 per ha., but this has increased to about Rs.1.5 lakhs to Rs.1.8 lakhs per ha., i.e. 10 times, when shrimp farming gained popularity. The ownership pattern of land has also radically changed. About 20 percent of the coastal land holdings were sold to big aqua farms as the size of the lands were small (less than one ha). 40 percent were sold due to high price, 30 percent due to inadequately profitable crop production and 10 percent because of non-availability of labour.

Conflict

The opposition to shrimp aquaculture stemmed from both environmental and socio-economic problems. The socio-economic problems arise from issues like land alienation, displacement of coastal communities from open access public lands used for fish drying, net drying, grazing, subsidence cultivation, etc., Additionally, the conversion of paddy lands, resulting in the loss of employment and local level food security and problems of access to the sea for fishermen, were also encountered in many areas.

In the wake of its growth, the aquaculture shrimp industry farming also posed a number of social, ecological and economic issues mainly on account of improper planning and unregulated and uncontrolled growth of the enterprise. The experience gained in the Asian countries including India, has clearly shown that if this activity is not scientifically managed and judiciously monitored it will not be sustainable and may cause a number of environmental and social problems, as well as increased incidence of disease outbreaks. It is therefore, necessary that the various issues encountered during the past be given careful consideration while developing future strategies for the sustainable development of this sector.

Hedonic Pricing Model for Land Quality

The hedonic pricing approach is based on the assumption that the environmental factors are attributes of goods or factors of production that are traded in the markets. The benefits/ damages, according to this approach, due to improvement/decrease in the environmental quality could be captured through the market price of the related goods.

This is modelled as follows:

$P_L = f(X_1, X_2, X_3, X_4, \ldots\ldots X_n)$ ....(1)

The above model describes the relationship between the price of land and other independent variables affecting the land price, including the environmental quality. More precisely, P_L the dependent variable, stands for the price of land and $X_1, X_2, X_3, X_4, \ldots\ldots X_n$ refer to the independent variables, including the soil quality, which are assumed to influence the price of land.

In the study, it is assumed that the price of the land in the affected areas is lower than that of the non-affected areas by aquacultural activities. This is described as follows:

$P_{ag} (X, X_1, X_2, X_3, X_4, \ldots\ldots X_n) > P_{ab} (X_1, X_2, X_3, \ldots\ldots X_n)$.........(2

Apart from the soil quality, the land price is affected by N number of other variables described in the model. To understand the nature of influence of these variables, including soil quality, a log-linear regression model is used, which is as follows:

$$P_L = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + \ldots\ldots + b_n X_n + z$$

In this model, α is the constant and β is the coefficient and **z** is the error term. If **X** value were substituted with the variables derived from the farmers' survey, it would be able to predict the nature of the influence of the independent variables on the land prices in affected and non-affected areas. One of the aspects to be noted is that even though the mean value of the price of the land differs between the two time periods, it is not sure whether the difference is 'statistically significant'. Testing the statistical significance in the land price is a necessary condition because, if the difference in the land price were not statistically significant, then the underlying assumption in the hedonic pricing model would become meaningless. To understand the statistical significance of the difference in land price, 'Paired Samples T –Test' has been used.

The mean value of the difference in the land value between the two time periods under consideration stands at Rs.22,510.8. Since the study is more concerned in understanding the statistical significance of the difference in the land values, the t-value is worth noting here. It should be noted that the t-value is significant at one percent error level. This means that the difference in the land value between the two time periods is highly significant.

The important point to be noted is that the price of the land, rather than declining due to the environmental impact of aquaculture, has increased in between the two time periods. As noted before, the difference in the land price might have been caused by other factors as well. In other words, the negative influence of the environmental impact on land price might have been offset by the positive impact of the other factors. This needs to be investigated further so as to understand the nature and extent of the influence of various factors on land price.

Willingness to Pay (WTP)– The Model

As in the case of the hedonic pricing model discussed above, the WTP value for the pollution control measures at the farm level by the owners of the farm depends on different kinds of factors. This can be described as follows:

$$WTP_{PC} = ¦ (PC_{0i}, PC_{1i}, Y_i, S_i) + z_i$$

WTP_{PC} stands for the WTP value of the i[th] farm owner

PC_{0i} refers to the prouder surplus <u>without</u> pollution control measure

PC_{1i} refers to producer surplus with pollution control measure

Y_i, income of the farm owner

S_i refers to other variables affecting the WTP value

z stands for the error term.

To understand the influence of each variable on the WTP value, the following log-linear regression model will be used:

$$\text{Log}_{WTP} = a + \text{Log } b_1 X1 + \text{Log } b_2 X2 + \text{Log } b_3 X_3 + \ldots\ldots + \text{Log } b_n X_n + z$$

It should be noted that the WTP value for the treatment of effluents emanating from the aqua farms is influenced by certain factors. Some of these factors influence the WTP value more strongly, and the influence of some other factors is only minimal.

The variable size positively influences the WTP and the influence is highly significant. This suggests that the larger the size of the farm owned by the respondent, the higher the WTP value. In the case of initial investment made by the respondent, represented by the variable capital, the influence is negative, which means that if the size of the initial investment made is greater, the willingness to pay for treatment is less and vice versa. However, the influence of the size of the initial investment on the WTP value is not significant. But the size of the variable cost (i.e. operational) influences the WTP value negatively and significantly. This implies that if the variable cost in running the farms at present is high, then the WTP value, which would add to the existing variable cost, would be less and vice versa. The volume of effluent represented by the variable volumeff, positively influences the WTP value but not significantly. Another important variable that influences the WTP value significantly is the annual income. The sign and the magnitude of this variable suggest that the respondents who derive more amount of annual income from the aqua farms are willing to pay more for treating the effluents.

Another factor that potentially determines the WTP value is whether the capital employed is borrowed or owned. The sign of the variable suggests that if the capital is borrowed, then the level of WTP value is less and if it comes from their own sources, then the WTP value is higher. However, the influence is not significant.

Regression Model for Agricultural Productivity

$Y = a + b_1$ paddy $+ b_2$ fertiliser $+ b_3$ source $+ b_4$ category $+ b_5$ existence $+ b_6$ awareness $+ b_7$ frequency $+ b_8$ salinity $+ z$

- The cropping pattern (indicated by the variable Paddy) is found to positively influence the productivity. This means that the productivity is found to be greater in those areas where paddy is being cultivated rather than other crops.
- The amount of fertilisers used (expressed in value term) is found to significantly influence the productivity. Other things remaining the same, the more the amount of fertiliser used, the greater the productivity in the study area.
- The source of irrigation is also found to positively influence the productivity. The productivity is found to be higher if the crop is irrigated with surface water rather than the ground water.
- The level of productivity also depends on the farmer's category. The productivity is higher for the large farmers category to the small farmers.
- Existence of aqua farms within a 3 km circle positively influences the productivity, but not significantly.
- If farmers are more aware of the environmental damages caused by aqua farms, then the productivity is found to increase. This may be due to the fact that the farmers may take up some defensive measures against the ill effects of aquacultural farms.
- The frequency of cultivation is also found to increase the productivity.
- There is no correlation between the general soil salinity and the productivity. This may be due to the fact that farmers may apply more amounts of fertiliser to mitigate the ill-effects of soil salinity.

The productivity measured in terms of net farm income, is expressed in terms of average net farm income between different areas in the aqua farm region. It may be noted that the average net farm income in the three areas i.e., less than 1 km, 1 – 3 km and above 3 km does not differ much. However, the difference between less than 1 km distance and above 1 km distance is greater than that of 1 – 3 km and above 3 km distance. Note, this simple analysis reveals much about the statistical significance of the difference in the net farm income. Hence, we have used a regression analysis to find out the productivity difference caused by the distance between the location of the agricultural land and the aquaculture farms.

Pollution Cost Abatement using ETS

To overcome the environmental constraints of disposing the farm effluents in a safe manner without conflicts, the Aquaculture Authority has made it mandatory that all shrimp farms of 5.0 hectares water spread area and above located within the CRZ, and 10 hectares water spread area and above located outside CRZ, should install an effluent treatment system (ETS) or effluent treatment facility so that the shrimp farms effluent's effect could be minimised within the prescribed standards and mitigate any adverse impact on the ecology of the open waters.

For aqua farms, an Effluent Treatment System (ETS) is proposed recently which consists of 3 types of ponds viz., settlement ponds, bio-ponds and aeration ponds. The cost estimate for the construction of a 0.5 ha proposed ETS is Rs.5,48,200 /-

Management Measures

Based on these conflicts, the productivity rate of aquaculture in some areas of Tamil Nadu and Pondicherry areas met a downfall, mainly due to the havoc caused by the opposition groups against aquaculture. Therefore, these issues were analysed to identify the areas for increased productivity and for appropriate research, development and policy interventions. Evolving appropriate polices and development of sustainable shrimp farms in India is handicapped by the non-availability of quantitative and qualitative scientific data on the factors responsible for degradation of the environment. Therefore, the environmental impacts remain largely speculative and unproven.

- Intensification / diversification of farming systems has received hardly any attention, in spite of technological possibilities for productivity advance, rural income and employment generation.

- Further, the envisaged growth cannot be achieved through technological intervention alone in the absence of development efforts and benign public policies. Sustainability from both ecological and economic angles is important, so that the country could lead in the progressive export trade of aqua products.

- Development and extensive adoption of location-specific farming aiming at higher productivity, better returns and year-round employment would help to improve the quality of life inhabiting the long coastal areas.

- High investment in research and development coupled with favourable public policies are important for achieving sustainable growth in production of shrimps, when the existing base and technological strength would be too inadequate to meet the future production challenges.

- The contemplated research and development strategies towards achieving the production goals should be ecologically and economically viable, causing the least damage to our fragile natural ecosystems/ foundations.

- Adequate consideration given to legal and social aspects, policies lay out, enforced through legislation, will ensure the carrying capacity of the ecosystems.