Chapter 1

INTRODUCTION

1.1 Introduction:

The economy of human activity continuously consumes natural resources. These are distinctly of two kinds: a) resource capable of self-regeneration, b) resources without having capability of self-regeneration. The first category of resources is called renewable resources. Being capable of self-regeneration, this category of resources could provide society with an essentially endless supply of goods or services. But the second category of resources is called non-renewable as its available fixed stock could only be depleted with the use over time. That is why this type of resources is specifically called 'exhaustible' resources. However, human society possesses capacities both for conservation and for destruction of the renewable base as well (Clark, 1973). Thus both types of resources are capable of total exhaustion (Smith, 1968). In producing and consuming goods and services, economic activities & society draw heavily on materials and energy from nature. These activities affect the environment in diverse ways, such as converting and defacing wetland, denuding the forest, over harvesting lakes and ocean, polluting the water and the air by industrial wastes etc. There is no dispute that these economic activities should be brought under scientific management and control.

The renewable resource is viewed as an asset from the capital theoretic point of view. The necessary conditions for deriving benefits of endless supply of goods and services from an asset are prudent use and optimal management of the asset. This efficient management sought an equilibrium point under three mutually conflicting objectives: 1) optimizing long term social benefits from a limited natural resource base, 2) minimizing resource use and environment degradation and 3) regulating the rate of use of these resources over time. Appropriate management policy of such resources thus much depends upon the results and analysis of renewable resource economics.

However, the degradation of renewable natural resources not only threatens the economic prospects of future generations but the livelihood of the current users as well. A large number of people in our country are dependent on renewable natural resource based subsistence. Thousands of people depend on agrarian, pastoral and fishing activities. It is believed that the social discount rate in our country is high as there is no alternative viable economic activity available to these people for their subsistence. This situation creates incentives for people to overexploit existing resources in order to survive. The management of renewable resources with the objective of optimal exploitation as well as conservation is not an easy task in India but a complicated one.

In India, renewable resources play a vital role in the national economy. Not only that the livelihood of major part of our population depends on renewable resources as it employs thousands of people in the process of resource exploitation and utilization but its contribution to Gross Domestic Product (GDP) is significantly higher than other sectors. It is important for foreign exchange earning as well. Though its contribution to total export shows a declining trend since 1987-88 its percentage share is more than fifty at present (Table- 1.1). Among different sub-sectors of these renewable resources, fishery is a major one.

Table- 1.1: Renewable and non-renewable resource contributions to export.

Resource/year	87-88	91-92	95-96	99-00	2003-2004P
Renewable	71.67	67.44	66.5	67.88	51.75
Nonrenewable	23.74	29.04	28.26	27.48	40.69
Others	4.59	3.52	5.24	4.64	7.56
Total percent	100	100	100	100	100

Source: Reserve Bank of India.

1.2 Indian fisheries.

Indian fisheries are divided in two types- capture fisheries and culture fisheries. The following table-1.2 shows the divisions in Indian fisheries.

Table-1.2: Divisions of Indian Fisheries

<table>
<tr><td colspan="11">Indian fisheries</td></tr>
<tr><td colspan="6">Capture</td><td colspan="5">Culture</td></tr>
<tr><td colspan="4">Inland</td><td colspan="2">Marine</td><td rowspan="2">Fresh water</td><td rowspan="2">Cold water</td><td rowspan="2">Brackish/ Coastal water</td><td rowspan="2">Mari culture</td><td rowspan="2">Ornamental</td></tr>
<tr><td>Rivers and their floodplains</td><td>Estuaries</td><td>Reservoirs</td><td>Upland resources</td><td>Coastal</td><td>Deep sea</td></tr>
</table>

We have shown GDP contributions (Appendix-1) of Agriculture and Fishery in Indian National Economy along with fishing as a percentage of agriculture since 1970-71. It is revealed that the contribution of fishing as a percentage of GDP rose to 1.19 from 0.61 in 1970-71. Similarly, fisheries contribution to agriculture rose to 5.89 percent from 1.40 in 1970-71. Growth rate of fishing is much higher than national GDP growth. In table-1.3 we have shown fish production in different plan periods separately for marine and inland fisheries.

Table – 1.3: Fish Production in different plan periods and average annual growth rate.

Plan period	Fish production at the end of the period ('000 tonnes)			Growth (per cent) during the plan period.			Average Annual growth rate
	Marine	Inland	Total	Marine	Inland	Total	
Preplan 50-51	534	218	752	-	-	-	-
1st (51-56)	596	243	839	11.61	11.47	11.57	2.31
2nd (56-61)	880	280	1160	47.65	15.23	38.26	7.65
3rd (61-66)	824	507	1331	-6.36	81.07	14.74	2.95
Annual plans (66-69)	904	622	1526	9.71	22.68	14.65	4.88
4th (69-74)	1210	784	1958	33.85	20.26	28.31	5.66
5th (74-79)	1490	816	2306	23.14	9.09	17.77	3.55
Annual plan (79-80)	1492	848	2340	0.13	3.92	1.47	1.47
6th (80-85)	1698	1103	2801	13.81	30.07	19.70	3.94
7th (85-90)	2275	1402	3677	33.98	27.11	31.27	6.25
Annual plan (90-91)	1300	1536	3836	1.10	9.56	4.32	4.32
Annual plan (91-92)	2447	1710	4157	6.39	11.33	8.37	8.37
8th (92-97)	2967	2381	5348	16.76	33.51	23.65	5.17
97-98	2950	2440	5390	-0.58	2.48	0.78	0.78
98-99	2700	2560	5260	-8.47	4.91	-2.41	-2.41
99-2000	2830	2820	5650	4.81	10.15	7.41	7.41
2000-2001	2900	3050	5950	2.47	8.15	5.31	5.31
2001-2002	2970	3290	6260	2.41	7.86	5.21	5.21

Source: 1) Central Marine Fisheries Research Institute, Kochi for the period up to 1970-71.
2) State Governments/ Union Territory Administrations since 1970-71.

We describe the Exclusive Economic Zone (EEZ) of Indian Marine resources in figure -1.1 and expected potential of marine and inland resources in table 1.4. The table shows that the Geographic base of Indian marine fisheries has 8118 kilometers. coastline, 2.02 million square kilometers of Exclusive Economic Zone (EEZ) including 0.5 million square kilometers of continental shelf.

Figure -1.1: Indian EEZ

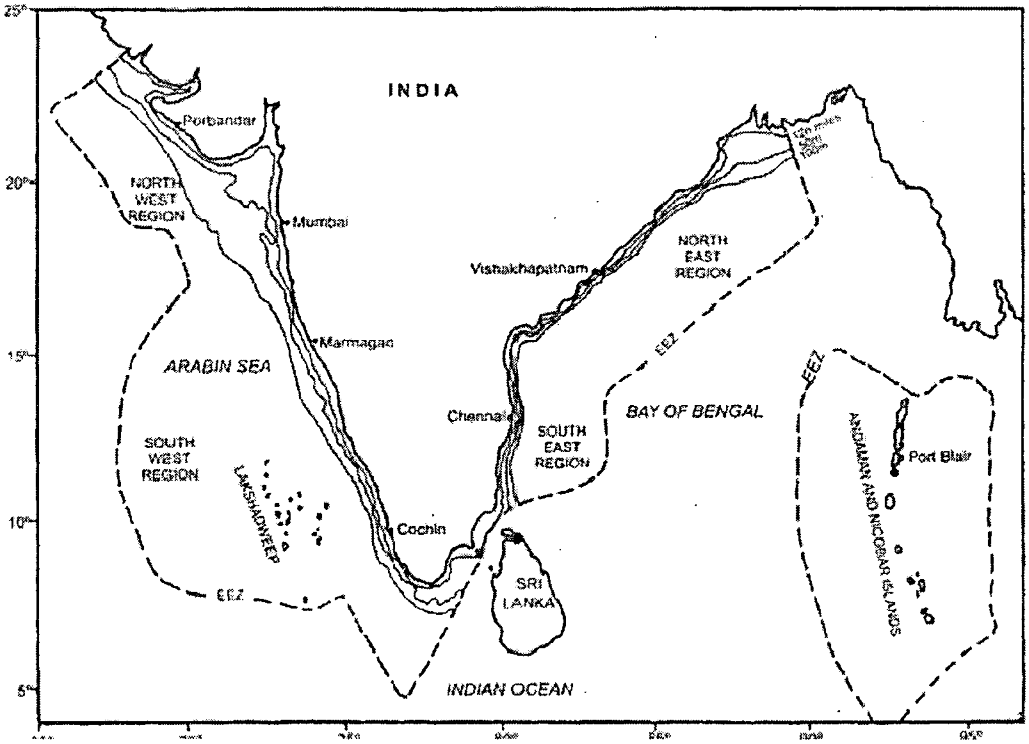


Table-1.4: Marine Area and Potential Resources.

1.	Length of coastline	8118 km
2.	Exclusive Economic Zone (EEZ)	2.0 2 million sq. km
3.	Continental shelf area	530000 sq. km
4	Length of rivers, canals	191204 km
5.	Brakishwater area	1.24 million hector
6.	Reserviors area	3.15 million hector
7.	Tanks and ponds	2.25 million hector
8.	Beels, ox-bow &derelict waters	0.82 million hector
9.	Marine fish potential	3.93 million tonnes
10.	Inland fish potential	4.50 million tonnes

Source: Central Marine Fisheries Research Institute, Kochi

Although India has a large coastline, enough marine resources, and vast continental shelf area and also a number of inland fisheries, the contribution of fisheries towards India's GDP is negligible, around 1.2 percent at an average for the ten years ending in 2005 as shown in appendix-1. Indian marine resources are entitled to be exploited by the state as well as central government. According to the Seventh Schedule, Article 246 of the Constitution of India, fisheries within the territorial waters of India (i.e. up to 12 nautical miles or depth up to 50 meters) are under the jurisdiction of the State Government and fishing and fisheries beyond territorial waters within the EEZ are under the jurisdiction of the Central Government. There are 1896 traditional fish landing centres, 33 minor fishing harbours and 6 major fishing harbours 3937 fishing villages. Approximate coast length, area of continental shelf, number of landing centres & number of fishing villages of thirteen maritime states[1] are given in table 1.5.

Table- 1.5: Area of continental shelf, number of landing centres & number of fishing villages of Maritime States

State/Union territory	Appx. Length of coastline (kms)	Continental shelf ('000 sq. km)	No of landing centres	No. of fishing villages
1. Andhra Pradesh	974	33	508	508
2. Goa	104	10	88	72
3. Gujrat	1600	184	286	851
4. Karnataka	300	27	29	221
5. Kerala (P)	590	40	226	222-
6. Maharashtra	720	112	184	395
7. Orrisa	480	26	63	329
8. Tamilnadu	1076	41	362	556
9. West Bengal	158	17	47	652
10. Andaman & Nicobar Island (P)	1912	35	57	45
11. Daman & Diu (P)	27	-	7	31
12. Lakshadweep (P)	132	4	11	10
13. Pondichery	45	1	28	45
Total	8118	530	1896	3937

Source: State Governments/ Union Territory Administrations. (P) indicates provisional.

But many studies claim that Indian marine resources are not fully exploited till now. Demersal and pelagic resources in different depths have a total potential of 3.92 million tonnes of which only 61 percent is exploited. It is also reported that 39.12 percent of demersal and

[1] Please see discussion 4.3

26.98 percent of pelagic resources remained unexploited at the of 1998 [details of present position is discussed in Chapter-2].

1.3 Brief view on marine fishery fleet of India:

The Indian marine fishing activities were mostly confined to the coastal zone until mid 80's. After this period the fishing zone was marginally extended beyond coastal zone for catching mostly deep-sea lobster, shrimps and also cephalopods. The major significant change that had been observed in Indian marine fishery (especially in the coastal region of south) was modernization program under Indo-Norwegian project by Union Department of Agriculture in the 1950's. Successful implementation of the project not only changed individual boats into the mechanized one by the installation of inboard engines but later introduction of mechanized boats of convenient new designs was also made possible. Subsequently in late 1970's Union Cabinet first introduced medium sized outrigger trawlers along the upper east coast followed by imports of 25 m length overall (LOA) trawlers essentially for marine shrimping. However these were also equipped for stern trawling. Indigenously constructed similar trawlers were introduced in Indian marine fishing till late 80's. Indigenously constructed mini trawlers in 15m LOA range were introduced in the later part of this period by private fishing enterprises for coastal shrimping and purse seining in the coastal zone.

In the year 1976, EEZ of India was notified. Government of India (GOI) notified the regulations to control fishing by foreign vessels in the Indian EEZ in 1981. Declaration of EEZ and subsequent GOI notification (1981) did fail to deter foreign vessels harvesting within Indian Territory by taking advantage of the provisions of the scheme of joint ventures. On the basis of the recommendations of Murari Committee, the GOI abolished the scheme in 1994.

Abolishing this scheme in 1994, however failed to achieve its objective in preventing Taiwanese vessels into Indian EEZ. The owners of Taiwanese vessels are understood to have availed of the facilities used the newly introduced system which permits to import used large vessels. Besides the process of liberalization of economy, which began gradually in the early

1980's and formally declared in the early 1990's, permitted many new joint venture agreements for fishing in the Indian EEZ beyond 12 nautical miles of territorial waters (Kurien, 2000). Meanwhile the real Indian (medium length) fleet of 23-27 m overall length (OAL) declined to 50 numbers only from 195 in the year 2003 (Fishing Chimes, 2003).

Scenario within 12 nautical miles is completely different. Within 12 nautical miles of coastal zone we have thousands of different types of fishing vessels- motorized and non-motorized traditional crafts, mechanized boats of different size and facilities. Numbers of boats are also increasing rapidly over the years which cause massive overcrowding and as a result overexploitation in certain regions of EEZ.

Motorized boats which predominantly operate within 50 meters of depth (or within 12 nautical miles) increased from 6928 in 1985 to 39303 in 1995 to 44578 in 2003. Similarly mechanized boats increased for 26733 in 1985 to 37901 in 1995 to 53684 in 2003. Intensified harvesting activities by thousands of vessels crowded in this zone put pressure on biomass stock. Effort being increased, many experts opined that we are spending more and more, to catch less and less fish per unit of effort (Kurien, 2000). Indian fisheries sector (both marine & inland) have grown several folds in the past five decades, but have raised several issues relating to optimal utilization and sectoral allocation of marine fishing fleet.

But India has been facing a constantly alarming trend of deterioration in the performance of its marine fisheries sector, in terms of fleet strength and consequential exploited output for the past several years (Fishing Chimes, 2003). Although Indian marine fleet increased in numbers but still they could not harvest in accordance to the potential yield.

The present fleet strength of India is shown in the table-1.6 below.

Table-1.6: Present marine fleet strength of India.

State/Union territory	Non motorized traditional crafts	Motorized traditional crafts	Mechanized Boats	Total
1. Andhra Pradesh	53853	4164	8642	66659
2. Goa	1094	1100	1092	3286
3. Gujrat	9222	5391	11372	25985
4. Karnataka	19292	3452	2866	25610
5. Kerala	28456	17362	4206	50024
6. Maharashtra	10256	286	8899	19441
7. Orrisa	10993	2640	1276	15854*
8. Tamilnadu	33945	8592	9896	52433
9. West Bengal	4850	270	3362	8482
10. Andaman & Nicobar Island	1180	160	230	1570
11. Daman & Diu	252	350	805	1407
12. Lakshadweep	594	306	478	1378
13. Pondichery	7297	505	560	8362
Total	181284	44578	53684	280491*

* total includes 810 FRP Catamarans and 135 Beach Landing Crafts.

Source: Fishing Chimes, August 2004.

From table-1.6 we see that, out of 280491 fishing crafts only 19.14 percent are mechanized boats. It includes trawlers, purse-seiners, long liners, gill-netters etc. Though numbers of mechanized boats were only very few comparing the total fleet strength, but it contributed 65 percent of the total fish landings 2.46 million tones on the average during the period 1988-1997 (MOA, 1996). Thus productivity of the Indian marine fishery depends mainly on the efficiency of different types of mechanized vessels that we have mentioned.

1.4 Problem of the study:

Indian marine resource was mainly exploited by artisanal fishermen as a means of theirs subsistence before independence and during the early phase of our independence. Commercial fishing activities were developed by introduction of trawling and purse seining techniques later. The commercial fishing requires estimation of fish stock. Both intensive and extensive surveys were undertaken to provide necessary estimates of bio-mass stock during this period. The findings of those initial surveys led to the recommendation of a development program that emphasized the necessity of mechanization of indigenous crafts. As a part of modernization program, the Indo-Norwegian Project helped artisanal fishermen to convert their individual traditional crafts into mechanized boats. But the rapid development of commercial marine fisheries is basically the post EEZ phenomenon. The marine fish production registered manifold increase in fish capture during the period 1960 to 1996. It was only 0.85 million tones in 1960 but rose to 2.94 million tones in 1996. It also implies growth and changes in fishing capacity i.e. fleet types and strength.

Fishing fleet that operate in the coastal inshore and off- shore waters, can be grouped into three major categories: 1) non-motorized traditional crafts, 2) motorized traditional crafts and 3) mechanized boats. The detail of the categorization according to the marine fisheries experts is done in chapter 2. The present fleet strength of the different categories of boats is 280491 of which 181284 are non-motorized traditional crafts, 44578 are motorized traditional crafts and 53684 are mechanized boats (Fishing Chimes, 2004). This mechanized category includes trawlers, purse-seiners, long liners, and gill-netters etc. These may be again sub grouped according to their length, horsepower and facilities available on board.

In India, the areas below 50 meters of depth (corresponding to 12 nautical miles distance from the shore) reserved exclusively for motorized and non-motorized traditional crafts as well as small-mechanized boats by legislation. A few mechanized boats started harvesting beyond 50 meters of depth by extending their area of operation. Thus Indian marine fishing capacity increased in terms of area and operation (both horizontal and vertical) as well as total installed fishing effort with respect to increased number of boats.

Fishery Survey of India (FSI), an agency of GOI, responsible for surveys and assessment of the marine fishery potential of the Indian EEZ estimated the maximum sustainable yield (MSY) of the fish stock as 3.93 million tones per year. It includes demersal

(1.93 million tones), pelagic (1.74 million tones) and oceanic (0.25 million tones) resources per year (Sudarsan et.al 1990). However, the total marine fish production is only 69 percent of the total potential. While 91 percent of the total potential within 50 meters of depth is being exploited, only 46 percent of the total potential per year is exploited within the range of 50 meters to 200 meters of depth. Moreover almost entire oceanic potential is left unexploited in India. Also, the number of vessels capable of harvesting beyond 50 meters of depth has decreased. Thus there are different inter-dependent facets of the Indian marine fishery problem: at the one hand, number of boats operating within 50 meters of depth is continually increasing and on the other, number of vessels operating beyond 50 meters of depth is decreased to almost one-fourth of its original strength. In the first case, there is a possibility that the vessels are suffering from scale efficiency because of crowding of vessels apart from pressure on biomass stock. In the second situation, since harvesting in the deep-sea depends upon application of technology as well as minimum viable level of scale, vessels are suffering from overall efficiency. Problems of Indian marine fisheries has not been studied and analyzed from these points of views. It was not analyzed from the aspect of determination of capacity output and capacity utilization. Both of the two aspects are related with the determination of efficient frontier analysis of many vessels operations. It is important to note that even within 12 nautical miles, the level of marine production have not been reached to the fullest of its estimated MSY. But many experts have already observed symptoms of depletion within this zone. It is important two understand how these two apparently conflicting phenomena can be reconciled. MSY is a biological point of equilibrium. It is accepted that MSY concept is, in many respect, far too simplistic to serve as a valid "operational" objective for the management of most living resource stock (Clark, 1990). Even severe objections have risen on biological grounds. However, the economic shortcomings of this concept are even more important. This concept totally ignores the cost aspects of harvesting operation. Thus it is quite impossible that an MSY harvest policy is not likely to be proved optimal in an economic sense.

Another aspect that this conflicting observation seems to indicate is that the vessel distribution in different patches of fishing zone is not in accordance with the density of bio-mass stock in different patches. This, therefore, is indicative of sub-optimal allocation of effort. Problem of the study, therefore, urges to analyze the allocative justification of inputs and its utilization with respective to potential output of marine resources of India.

1.5 Rationale of the study:

Among different sectors of renewable resources in India, fishing is one of the most important. Thousands of people are employed directly or indirectly in this sector. It contributes substantially to total foreign earnings through exports. It has continuously been contributing to the GDP growth. Moreover, the total potentiality of resources has not been fully exploited so far the calculated MSY is concerned. It indicates that the growth of Indian GDP may be higher, had the marine resources been exploited to the extent of its potentiality.

National committee on cattle in its report laid down the following objectives of fishery policy: 1) to augment marine fish production of the country up to the sustainable level in a reasonable manner so as to boost export of sea food from the country and also to increase per capita fish protein intake of the masses, 2) to ensure socio-economic security to artisanal fishermen whose livelihood solely depends on this vocation, 3) to ensure sustainable development of marine fisheries with due concern for ecological integrity and bio-diversity. However, the report at the same time pointed out " exploitation of the living resources within 50 meters of depth zone is showing symptoms of depletion and in certain belts in the inshore waters it tends to cross optimum sustainable level". The report, therefore, suggest a stringent fishery regime (management system) to be in place.

Despite the rapid development of methodology of frontier approaches and its applications in different sectors of economy, research on technical efficiency in commercial fisheries is rather limited. It is alleged that different authorities of fishery management are typically more concerned with the biological aspects of fisheries resources rather than with the economic performance of various agents or factors involved in fishery (Sharma & Leung, 1998). Management generally emphasizes more on resource conservation and its maintenance rather than improvement of economic performance (Pascoe, Anderson & De Wilde, 2001). But there is no doubt that both the sustainable management of fish stocks and the efficient utilization of fishing inputs deserve to be considered in maximizing serial benefits. The above observation is particularly true for Indian commercial marine fishery.

Optimum fishery management demands not only the assessment of biomass stock that has been done by FSI, but at the same time demands to estimate both scale and technical efficiency of different types of fishing vessels. If we could obtain the efficient frontier of the vessel operation then only it is possible to suggest how the operation of the inefficient vessels would be placed on the frontier through input or output adjustments.

The present endeavor is, therefore, a humble attempt to make a comprehensive study of the state of fleet utilization in India with respect to capacity output. We would try to ascertain capacity utilization and limit capacity through data envelopment analysis (DEA). The study seems to carry an enormous academic value since no extensive study has been done on this particular aspect of Indian Marine Fisheries. It may be helpful to the government, to the researchers, to the national policy makers who has been making serious endeavor to protect the resources for sustainability as well as exploiting the resources to its fullest potentiality.

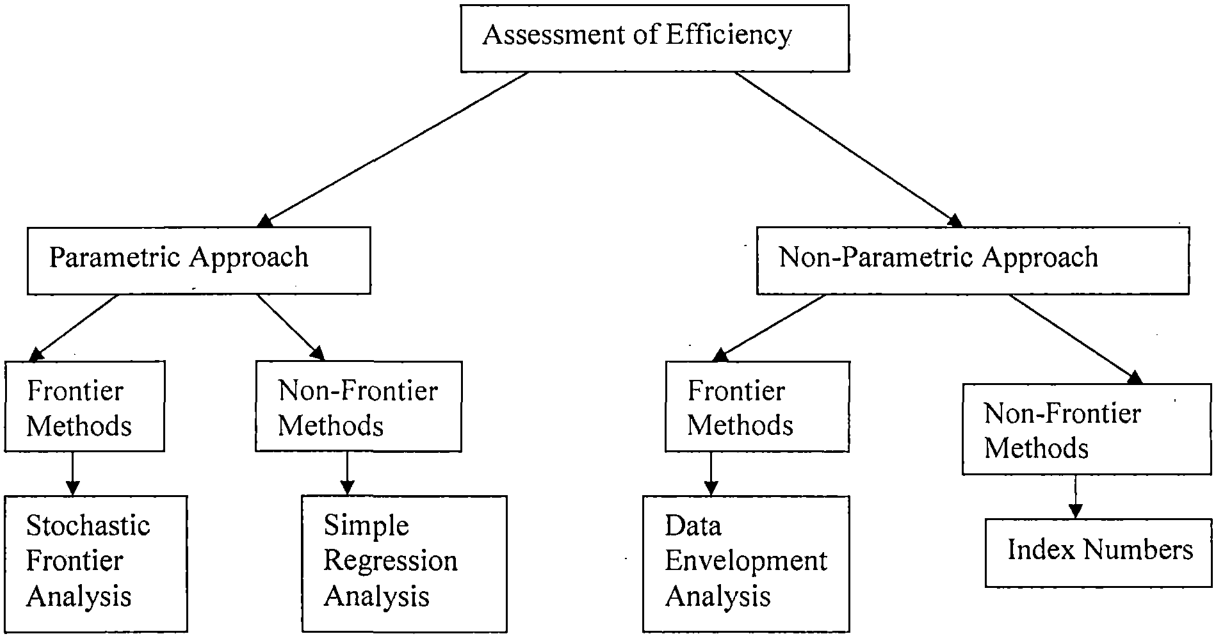
1.6 A brief overview of the literature:

Measurement of efficiency of economic activity is an attempt to assess the performance of industries or individual firms in using real resources to produce goods and services. The requirement of technical efficiency is that the maximum possible amount is produced with the resources used; or to put it in another way, it must be impossible to reduce the volume of any input without reducing the volume of output. Assuming that a deviation from optimum is possible in real production, an efficiency measure should reflect the difference between actual performance and potential performance. The better utilization of inputs/resources in the production process, the better is the efficiency. The literature presents a wide variety of methods used to measure technical efficiency. Frontier approaches evaluate productivity against production functions. A production function defines the maximum levels of output attainable with a certain combination of inputs or the minimum possible level of inputs to be used in the production of a certain level of outputs. In our study the literature review has been discussed in three parts: in the first section, study of all theoretical and empirical issues and their developments related to measurement of efficiency in general, which represents a review of the theoretical concept underlying the efficiency measurement of economic activity. In the second part, subsequently we present an overview of quantitative procedures, which can be used in estimating the relative performance of firms, within the framework of DEA and other studies related to application in fishery in particular. In the last part we will mention specifically relevant studies which contain a review of this method to fishing activity on Indian marine fishery.

1.6.1 A review of the theoretical concepts underlying efficiency measurement:

Optimal management of firms generally implies that, given the levels of input employed, the firm should produce maximum output. In order to attain overall economic efficiency, the firm, therefore, must be technically efficient, input allocative efficient and output allocative efficient (Kumbhakar & Lovell, 2000). Hence, efficiency can be considered in terms of the optimal combination of inputs to achieve a given level of outputs, or the optimal output that could be produced given a set of inputs. In case of fishery, while allocative efficiency affects the economic performances of the individual fisheries, technical efficiency affects the overall quantity of outputs produced from a given set of inputs. Level of efficiency of a firm is measured by the ratio between actual and potential productions. If a firm's actual production lies on the estimated efficient production frontier, the firm is said to be efficient. If it lies below the frontier then it is technically inefficient and the aforesaid ratio will determine the level of efficiency. A series of methods have been developed to estimate technical efficiency since the publication of Farrell's work on "Measurement of production efficiency". All such approaches for estimating technical efficiency, however, can generally be categorized under two distinctly opposite group of methods:- parametric and non-parametric (Seiford & Thrall, 1990). Stochastic Production Frontier Analysis (SPF) is an approach of the first type, while Data Envelopment Analysis (DEA) belongs to the second. The following tree (fig-1.2) shows the taxonomy of efficiency measurement techniques.

Figure - 1.2: Taxonomy of Efficiency Measurement Techniques



Imposition of an explicitly defined functional form is absolutely necessary for SPF with distributional assumption on data and a measure of random error. DEA, on the other hand, does not impose such functional form and, therefore, less prone to mis-specification (Wu, 1996). Further DEA is a non-parametric approach which does not require taking into account of random error. Hence it gets rid of problems of assuming an underlying distribution of the error term. However, since DEA can not take into account of such statistical noise, the efficiency estimates may be biased if the production process is largely characterized by stochastic elements (Mardle & Pascoe, 1999).

Efficiency estimates of SPF analysis also require several restrictions on function and also on input vector. The function is said to be finite, non-negative, real-valued and twice differentiable function. Moreover, it is assumed to hold monotonic property and must be strictly quasi-concave function. Because, the input requirement set is necessarily assumed to be closed and non-empty convex set. These restrictions rule out discontinuous jumps in the technology and permit the use of differential calculus in production analysis (Fousekis, 2000).

In the evaluation of trawler efficiency in marine fisheries require set of inputs as well as outputs data. SPF can not handle the multiple outputs. This deters to introduce SPF models in estimating overall efficiency of marine fishery. If stochastic components of marine fishery can be taken care of by the way of reducing the stochasticity effect in data series, then the application of DEA would have been better than SPF. The available data of marine fishery is generally annual harvest which is the aggregation of daily catch or per trip catch. Hence, much of the stochasticity is reduced by this aggregation. Moreover, there are a few very recent literatures in which the attempt is made to incorporate stochastic component in DEA method. Hence, comparing these two approaches with their relative advantages and limitations along with very nature of marine fishery data, the DEA method seems to imply better usability in our context.

1.6.2 Overview of quantitative procedures within the framework of DEA

Production efficiency concept was first introduced by Farrell (1957) which led to the development of series of work in the economics literature beginning with Aigner & Chu (1968). DEA introduced by Charnes, Cooper & Rhodes (CCR Model, 1978, 1981), and further extended by Banker (1980, 1984), and Banker et al. (1984, BCC Model) provides a non-parametric and extremal method for estimating production frontiers and evaluating relative efficiency of decision making units (DMU). The first DEA model (CCR) assumed constant returns to scale (CRS) while BCC extended the model to the situation variable returns to scale (VRS).

DEA analysis is based upon firms or in other words decision making units (DMU), each of which makes use of different inputs to produce different outputs. On the basis of input vector and output vector Charnes, Cooper and Rhodes (1978) introduced three concepts in the literature:

- Production possibility set: P ={(**X**,**Y**): **X**,**Y** >= 0, **Y** can be produced from **X**}
- Input possibility set: I(**X**) = {**X** : (**X**,**Y**) ε P}
- Output possibility set: O(**Y**) = {**Y**: (**X**,**Y**) ε P}

DEA does not require any information on input or output prices. In fisheries, prices on the main inputs are not easy to define and often are not even available. For this reason, the DEA models seem to be more appropriate. Moreover, a recent study (Pascoe, 2001) shows that several efficiency analyses carried out in terms of the physical inputs for different fleet segments of the North Sea provided similar results than when those analyses were carried out in terms of economic inputs.

Dyson *et al.* (2001) carried out a study on the advantages and disadvantages of the DEA method and on how to rectify some of the disadvantages. Also, Pedraja-Chaparro *et al.* (1999) studied the quality of the DEA models and the characteristics to be taken into consideration previously to the use of any of these models.

In 1978, Charnes, Cooper and Rhodes (CCR) proposed what has been traditionally considered the first DEA model. The CCR model was developed originally through a fractional form. The optimal values given by DEA are actually the virtual multipliers. Those represent the associated weights of the inputs and outputs respectively. The unit being evaluated will be called efficient if, by using the most favourable set of weights, the ratio of the weighted inputs over outputs is equal to one.The above fractional formulation can be transformed into a linear programming problem (LPP) (Charnes and Cooper, 1962) by maximizing the numerator and setting the denominator equal to a constant. In the DEA methodology, this constant is considered to be equal to one, in order to get an efficiency rate upper-bounded by one.

The models presented initially were input oriented models. Subsequently, the output-oriented model (CCR-O) was proposed where the efficiency has been defined as the ratio of the weighted sum of inputs to the weighted sum of the outputs. Generally for solution of DEA models dual form is used. When the unit under evaluation, DMU, is rated as inefficient, the solution to the dual problem provides a number of DMUs –the peer group or reference set- which is rated as efficient with the weights of DMU. Moreover, the optimal solution of the model provides a virtual unit on the frontier constructed as a linear combination of the units in the reference set. The unit being evaluated should be transformed into that virtual DMU in order to become efficient. This is made by a radial reduction of the inputs or expansion of the outputs –for an input or output orientation respectively- by means of the optimal value of objective function.

Several other overall efficiency measures have been proposed in literature. Some of those are called as additive DEA models. Several other traditional radial models (CCR and BCC) were suggested in Lovell and Pastor (1995), in Lovell, Pastor and Turner (1995) and in

Grifell-Tatjé, Lovell and Pastor (1998). Extensive review of various models is available in Cooper *et al.* (2000).

The original model of CCR assumed constant returns to scale (CRS). Banker, Charnes and Cooper (1984) extended their model and constructed a new model that allows for variable returns to scale (VRS). The extension is made by the elimination of the postulate of linear combination by the convex combination on the production possibility set P proposed in the CCR model. It makes the production possibility set as the smallest convex set that encloses all observed DMUs. In chapter 3 we have done a detail discussion of the DEA models required for our present study.

The method suggested by Banker (1984), is based on the concept of the most productive scale size and uses the CCR model. This method has been criticised by some authors (Chang and Ghu, 1991) who argued that Banker's test failed in some cases. However, Zhu and Shen (1995) proved that most of their arguments were wrong. The model works satisfactorily unless some of the efficient DMUs present linear dependency. They showed that there is a unique optimal solution to the CCR program and also unique most productive scale size would exist. Zhu and Shen developed a new technique to make the method work even when linear dependency occurs.

Golany (1988) proposed that some ordinal relationships could be established for the virtual multipliers. He presented a modified DEA model by introducing some more constraints. However, Ali, Cook and Seiford (1991) proved that some of the mathematical developments in Golany's work were wrong. Dyson and Thanassoulis (1988) proposed a solution for the single-input case. In their work, they suggested a way of determining an average for the weights by making use of regression analysis. These average values can be used to impose some lower bounds for the outputs weights. Wong and Beasley (1990) proposed the inclusion of value judgement in the DEA model by means of some new restrictions incorporated to the original models. The assurance region model developed by Thompson, Langemeier, Lee and Thrall (1990) also imposed some restrictions on the ratios among weights. Sengupta (1990) proposed some transformations in DEA models to establish a relationship between DEA and other parametric estimations of frontiers. Also in a very recent development Brazdik proposed the efficiency dominance principle to derive oriented chance constraint model for SDEA.

The major deficiency with DEA approach, as we have mentioned already, is that it is deterministic and hence does not take into account random error. However, more recently, stochastic Data Envelopment Analysis (SDEA) models have been developed. Since DEA is an extreme point technique, noise (even symmetrical noise with zero mean) such as measurement error can cause significant problems because the solution to optimization problems is sensitive to changes in data. As a consequence of this, theoretical attempts to incorporate these stochastic errors were made. SDEA applications are based on the theoretical paper by Land et al. (1993), where the authors used their new models to examine the efficiency of the same schooling program for disabled scholars as in Charnes et al. (1978). In Land et al. (1993), the authors discussed the prospect of stochastic data envelopment analysis and constructed their own model. They introduced the stochastic component to DEA and derived the model as a chance constrained version of BCC output oriented model in envelopment form. Further, Land et al. (1993) transformed these problems to their deterministic non-linear equivalents, which allowed them to determine the efficient DMUs.

Olesen and Petersen (1995) presented a different approach by incorporating the stochastic component into DEA. Olesen and Petersen assumed that the inefficiency of DMU can be decomposed into true inefficiency and disturbance term and derived the Olesen and Petersen model from the multiplier formulation of the BCC model. The approaches of Land et al. (1993) and Olesen and Petersen (1995) to SDEA are compared by Olesen (2002) and the weaknesses of both approaches are identified. The theoretical paper by Huang and Li sketches stochastic models with the possibility of variations in inputs and outputs and introduced stochastic efficiency dominance. Huang and Li defined the efficiency measure of a DMU via joint probabilistic comparisons of inputs and outputs with other DMUs that can be evaluated by solving a chance constrained programming problem. By utilizing the theory of chance constrained programming, deterministic equivalents are obtained for both situations of multivariate symmetric random disturbances and a single random factor in production relationships. Li (1998) obtained a linear deterministic equivalent via programming theory under the assumption of the single random factor and the stochastic supporting hyper-plane is use to analyze the returns to scale. The papers by Gstach (1998) and Simar (2003) show that there are research directions in which the future developments on DEA and SDEA may be driven. Gstach (1998) proposes using DEA to estimate a pseudo frontier (nonparametric shape estimation) and then apply a maximum likelihood-technique to the DEA-estimated efficiency to estimate the scalar value by which this pseudo-frontier must be shifted downward to get the true production frontier (location estimation). Simar (2003) proposes, for cases where noise to signal ratio is low, the bootstrapping method for improving the performance of the deterministic DEA frontier estimation. Mortimer (2002) in his comparative study of SFA and DEA literature summarizes the results from SFA and DEA studies to identify the amount of correlation between scores in SFA and DEA comparative studies. However, several stochastic DEA models have been developed recently. Banker and Maindiratta (1992) proposed a composed error model for the maximum likelihood estimation of non-parametric frontiers. Banker (1993a) proved consistency for DEA efficiency scores under certain conditions and established some relationships between DEA and maximum likelihood residuals. However these developments are not without problems (Olesen and Petersen, 1995). Banker (1993b) extended his previous model using two different approaches. Lovell *et al.* (1993) carried out a modified DEA model to get efficiency scores lower bounded by zero but unbounded from above. This modification allows the application of ordinary least squares to the logged modified DEA model scores. Retzlaff and Morey (1993) developed a stochastic model based on goal programming. They assumed equal input prices for all firms. This model was further studied by Resti (2000) using a multiplicative form. Simar and Wilson (2000a,b) also tried to provide some sort of confidence interval for the efficiency estimates in order to allow for random error using bootstrapping techniques. However this technique together with some other stochastic DEA models is not able to distinguish between the random effect and the inefficiency term. Moreover, Löthgren (1997) proves that in the presence of random noise, the bootstrapping technique increases error in the DEA estimates. The bootstrapping approach has had only limited application in fisheries.

1.6.3 Application of DEA in Indian Marine Fisheries.

Although, in fisheries, the technique of DEA has been applied to the Malaysian purse seine fishery (Kirkley *et al.*, 2003), United States Northwest Atlantic sea scallop fishery (Kirkley *et al.*, 2001), Atlantic inshore groundfish fishery (Hsu, 2003), Pacific salmon fishery (Hsu, 2003), the Danish gillnet fleet (Vestergaard, Squires and Kirkley, 2003), English Channel multispecies multigear fisheries (Pascoe, Coglan and Mardle, 2000; Tingley, Pascoe and Mardle, 2003), the Scottish fleet (Tingley and Pascoe, 2003) and the total world capture fisheries (Hsu, 2003), it is not yet tried in Indian marine fishery.

Fisheries research in India is coordinated by the Indian Council of Agricultural Research (ICAR), an autonomous organization under the Ministry of Agriculture. Several other Agricultural Universities and institutes under the Ministry of Agriculture also do the same. Generally fisheries studies in India are done from two different points of views. Either study is conducted to understand the biological aspects which consist of finding the fish stock in Indian EEZ or to estimate the biomass level or to find the fishery potential in the EEZ of India. The fact is, in India, different authorities of fishery management are typically more concerned with the biological aspects of fisheries resources rather than with the economic performance of various agents or factors involved in fishery (Sharma & Lenng, 1998). These biological surveys are conducted by Department of Animal Husbandry and Dairying (DAHD), Govt Of India, Fishery Survey Of India, Central Marine Fisheries Research Institute, Cochi. The other studies are related to the socoi-economic conditions of the fisher-folk of India. The Bay of Bengal Programme (BOBP) started in 1979 and still continues, providing assistance in the development of small-scale fisheries, including enhancing the socio-economical welfare of the fishing communities. Researchers and scholars are more interested in finding out MSY of capture marine fishery. The marine fishing capacity in the form of traditional motorized and mechanized boats is being assessed at institutional level. In one such exercise, the optimum fleet for different categories of crafts (CMFRI, 1998) was estimated. Also, Indian researchers are doing work on fisheries management, control, and surveillance in Indian EEZ (Somvanshi, 1996, 1999).

Since DEA is not being applied in Indian fisheries yet, there is no literature available in this regard for India. The advantages of this method are that it can estimate capacity under constraints including total allowable catch (TAC), by-catch, regional and/or size distributions of vessels, restrictions on fishing time, and socio-economic concerns such as minimum employment levels etc. DEA can be used to identify inefficient operating units (individual vessels). DEA readily accommodates multiple outputs (e.g. species, market categories), and multiple types of inputs such as vessel and crew. DEA can also determine the maximum potential level of effort and its utilization rate. The analysis accepts virtually all data possibilities, ranging from the most parsimonious (catch levels, number of trips, and vessel numbers) to the most complete (e.g. a full range of cost data). With cost data, DEA can be used to estimate the least-cost (cost minimizing) number of vessels and fleet configuration. It can also measure capacity relative to any desired biomass. The method is limited by its deterministic specification, but allows for the consideration of an economic definition of capacity. The present study could help the researchers, the national policy makers who has been making serious attempts to protect the Indian Marine Resources for sustainable developments as well as exploiting the resources to its maximum potentiality.

1.7 Objectives of the study:

The main objectives of the study are as follows:

1. To study the utilization of the Indian marine fishing fleet of the different maritime states, given the biological and geographical resources.
2. To find the efficient frontier of Indian maritime states with respect to few selected inputs.
3. To identify maritime zones which are operating efficiently with respect to input utilization.
4. To identify maritime zones which have excess capacity and under performing.

1.8 Hypothesis of the study:

Following are, therefore, hypothesis postulates for this study.

1) Indian Marine Fishery has not been fully exploited due to absence of optimal resource management policy.

2) Indian marine fishing fleet operating within 12 nautical miles (or 50 meters depth zone) is over capacitated and vessels are running inefficiently due to lack of scale efficiency.

3) Indian marine fishing fleet operating beyond 12 nautical miles (or 50 meters depth zone) or in deep-sea is running inefficiently due to lack of both scale and technical efficiency.

1.9 Sources of Data and Methodology of the Study:

The study is based on secondary data. Sources of secondary data are mainly published series of Department of marine fisheries, India; Department of Animal Husbandry and Dairying (DAHD), Government of India; Fishery Survey of India (FSI); Central Marine Fisheries Research Institute (CMFRI), of India; Bay of Bengal Programme (BOBP), Chennai, India; Food and Agricultural Organization (FAO); Reserve Bank of India (RBI); Central Statistical Organization (CSO); FISHSTAT PLUS & FAOSTAT database maintained by FAO; FIGIS, an official website maintained by FAO for statistical queries on fisheries database, etc. finding of a few scholars who worked on Indian Marine Fishery will be used whenever necessary. Fish landing data for different maritime states for the year 2003 are collected from Marine Fishery Information Service (MFIS, 2005). The published documents of Government and Non-governmental organizations are also consulted.

Between two types of technical efficiency – Debreau & Shephard- former is considered more appropriate for economic sector like fishing where producer has option to select input levels than output levels. Different alternative methods have been developed for the estimation of frontier function since the seminar paper of Farrell (1957). Between two categories of methods – parametric and non-parametric – we opt for the second approach. While the former is based on the econometric techniques and require assumptions in defining the functional form of the technology and the random error distribution, the later method relies on piece-wise linear deterministic frontiers. This approach does not necessitate functional forms and thus is less prone to error of misspecification. Another advantage is that the method can easily handle multiple inputs and multiple outputs. Moreover, since the method does not take into account stochasticity, the problem of assuming an underlying distribution about the error term does not arise. This particular non-parametric technique is called Data Envelopment Analysis (DEA).

Various DEA models are proposed in the literature of production frontiers (discussed in section 1.6). The assumption of constant returns to scale is not valid for marine fishery, hence the frontiers have assumed to be piecewise linear and concave characteristics. Since the BCC model has its production frontiers spanned by the convex hull of the existing DMUs and capture the characteristics of variable returns to scale, we choose to apply BCC model in its dual form. Further, since our objective is to optimize the output, given the input levels, we select the output oriented model.

1.10 Plan of the study:

The thesis spans over six chapters including the introductory one. Chapter 2 contains an account of present scenario of Indian Marine fishery with respect to development, management, control, potential harvest, existing fleet types & its strengths and optimal fleet size. This chapter will give us an overview of Indian Marine Fishery and its management problems.

Chapter 3 is planned to be dealt with measurement of efficiency & DEA. It will be a methodological review chapter where we discuss the relevance of efficiency measurement & DEA with respect to Marine fishery.

In chapter 4, we propose to estimate the Performance in Marine Fishery of Indian Maritime States using DEA for the years 2003 & 2005 and try to establish the improvement of efficiency from 2003 to 2005.

In chapter 5, we estimate the Efficiency of Indian Marine Fishery using DEA for the year 2005 with respect to the mechanized crafts and try to find out the most efficient maritime states in India.

Finally, chapter 6 summaries the conclusions of empirical results of the study. It also includes limitations and further scope of present study.