Modelling and Measuring the Efficiency of the Brackishwater Shrimp Aquaculture Sector & Its Socio-economic and Environmental Impacts on Rural Producers in Nellore District, India

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ABSTRACT

The lack of economic analysis on export-led shrimp farming in India has become of major national importance as a result of the Indian Supreme Court's December 1996 decision to ban the shrimp farming sector. The ban was a direct result of concerns over the impact of shrimp farming—in terms of its degradation of the environment and marginalization of local people from coastal resources. In addition to questions raised with respect to the nature and extent of environmental and socio-economic externalities of this sector, recent parliamentary debate raised equally important questions regarding the sustainability of shrimp farming under a variety of production methods. However, assessment of the productive efficiency of shrimp farms under increasingly intensive production methods is lacking.

Parametric and non-parametric approaches to measuring the productive efficiency of shrimp farms are applied to farm-level data collected from the Kandaleru region in India. First, technical efficiency is modelled, measured and explained by estimating a restricted translog stochastic frontier production function using maximum-likelihood methods. The variation of technical efficiency indices across the shrimp farm sample is explained using farm specific characteristics and managerial variables. Farm mechanisation, location and size are found to be significant factors explaining total inefficiency. Second, scale effects are extracted from the total efficiency index by applying Data Envelopment Analysis techniques. An inverse relationship is found to exist between farm size and efficiency.

Next, social and environmental impacts facing rural inhabitants as a result of the shrimp farming sector's growth and development are assessed using primary survey data collected from twenty-six villages located adjacent to shrimp farms. The most frequently cited problem by local inhabitants is blocked access to public areas. This is followed by problems of agricultural land salinity, well water salinity, unemployment, fodder & fuelwood collection problems and health problems, respectively.

The immediate policy direction is clear: larger farmers could reduce the intensity of production to maximise efficiency and minimise input slacks to reduce the risk of environmental degradation both within the aquatic pond environment and to the natural ecosystem. Similarly, they could enable free but supervised access through their farms to public areas such as the Bay of Bengal, Kandaleru creek or public pasture lands.

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TABLE OF CONTENTS

Part I:	**Assessing Shrimp Farming's Growth and Development.....**	12
Chapter 1:	An Overview of Asian Shrimp Farming & Its Impacts.........	15
Chapter 2:	A Discussion of the Survey Data & Methodology...............	52
Chapter 3:	An Analysis of Shrimp Farming's Growth & Development Along the Kandaleru..	86
Chapter 4:	Shrimp Farming & the Impact of Changing Land Use Patterns on Agricultural Labour..	113
Part II:	**Evaluating Indian Shrimp Farm Performance...............**	146
Chapter 5:	Parametric Analysis (Stochastic Production Function Approach)..	151
Chapter 6:	Non-Parametric Analysis (Data Envelopment Analysis)........	200
Part III:	**Assessing the Social Impacts of Shrimp Farming............**	237
Chapter 7:	An Empirical Investigation of the Socio-economic Impacts of Kandaleru Shrimp Farming..	243
Chapter 8:	Identifying the Determinants of Shrimp Farming's Negative Externalities..	284
Part IV:	**Conclusion...**	316
	References..	320

LIST OF TABLES

Table 2.0:	Location of 1997 Creek-Based Shrimp Farms Along the Kandaleru.....	67
Table 2.1:	Location of 1997 Sea-Based Shrimp Farms Along the Bay of Bengal..	68
Table 2.2:	Summary Characteristics of Surveyed Villages..........................	71
Table 2.3:	Reported Social & Environmental Impacts................................	74
Table 2B:	Primary Inputs and Descriptive Farm Characteristics....................	85
Table 3.0:	1997 Shrimp Farms by Size of Land Holdings............................	89
Table 3.1:	1997 Kandaleru Average Farms Size, Culture Area & Utilisation Rate.	90
Table 3.2:	Ownership Status by Size of Land Holding................................	91
Table 3.3:	Five Culture Techniques Defined by Stocking Density..................	93
Table 3.4:	Matrix of Major Production Input Correlation............................	94
Table 3.5:	Partial Productivity Ratios...	96
Table 3.6:	Average Output by Farm Size (1993/4 and 1996/7 Seasons)............	100
Table 3.7:	Number of Kandaleru Shrimp Farms & Share of Total by Size.........	101
Table 3.8:	Average Farm Size, Water Spread Area & Land Utilisation Rate........	102
Table 3.9:	Capacity of Ancillary Services in Nellore District.........................	105
Table 3.10:	Average Seed & Feed Inputs per Crop by Size............................	106
Table 3.11:	Growth Patterns of Ancillary Services......................................	110
Table 3.12:	Average Annual Growth Rates of Firms & Capacity Growth............	111
Table 4.0:	Private Land Purchase & Lease Prices (1989-1997)......................	116
Table 4.1:	Extent of Land Converted to Shrimp Farms...............................	122
Table 4.2:	Net Sown Area & Total Cultivators in Nellore............................	125
Table 4.3:	Area Under Shrimp Farming in Nellore District's Mandals..............	127
Table 4.4:	Labour Use Intensity Index..	128
Table 4.5:	Duration of Shrimp Production Phases.....................................	133

LIST OF TABLES (CONTINUED)

Table 4.6: Gender Divisions in the Shrimp Production Cycle........................ 135

Table 4.7: Average Daily Labour Requirements on Shrimp Farms.................. 136

Table 4.8: Average Total Labour Inputs Required per Production Phase........... 137

Table 4.9: Total Labour Requirements (person-days per water spread hectare)... 139

Table 4.10: Returns to Labour.. 140

Table 4.11: A Comparison of Total and Hired Labour Inputs for Seven Crops..... 143

Table 4A.1: Unskilled Workers Hired from Local Workforce by Culture Intensity 145

Table 4A.2: Unskilled Workers Hired from Local Workforce by Farm Size......... 145

Table 5.0: Summary Statistics for 82 Kandaleru Shrimp Farms..................... 171

Table 5.1: MLE for Two Selected Stochastic Frontiers (Two-Stage Approach).. 174

Table 5.2: Tests of Hypothesis: Farm Effects (Two-Stage Approach).............. 176

Table 5.3: Likelihood Ratio Tests for Model Selection (Two-Stage Approach)... 176

Table 5.4: Distribution of Technical Efficiency Measures (Two-Stage Approach).. 177

Table 5.5: Second Stage Regression Results Explaining Technical Efficiency.... 180

Table 5.6: MLE for Two Selected Stochastic Frontiers (Single-Stage Approach).. 182

Table 5.7: Tests of Hypothesis: Farm Effects (Single-Stage Approach)............ 184

Table 5.8: Likelihood Ratio Tests for Model Selection (Single-Stage Approach) 184

Table 5.9: Chi-Square Test of the Inefficiency Effects (Single-Stage Approach) 185

Table 5.10: MLE for Three Selected Inefficiency Models (Single-Stage Approach).. 187

Table 5.11: Likelihood Ratio Tests for Model Selection (Preferred Model)........ 188

Table 5.12: Distribution of Technical Efficiency Measures (Single-Stage Approach).. 189

Table 5.13: Technical Efficiency by Size of Farm...................................... 193

LIST OF TABLES (CONTINUED)

Table 5.14:	Technical Efficiency & the Production Environment.........................	194
Table 5A.1	Efficiency Indices...	199
Table 6.0:	Pure Technical, Scale and Total Efficiency Indices (Non-Parametric)	214
Table 6.1:	Efficiency and Farm Size: Production Intensity and Feed Use..........	215
Table 6.2:	Returns to Scale in the Shrimp Farming Sector.............................	217
Table 6.3:	Input Slacks...	221
Table 6.4:	Explaining Economies of Scale..	224
Table 6.5:	Pearson, Spearman, and Kendall Measures: Feed Use & Efficiency...	230
Tablr 6.6:	Summary of Efficiency Measures: Parametric *v* DEA...................	232
Table 6.7:	Pearson, Spearman, and Kendall Measures: Parametric *v* DEA.........	234
Table 7.0:	Impacts Identified by Kandaleru Villages..................................	247
Table 7.1:	Social Impacts Ranked by Frequency.......................................	248
Table 7.2:	Summary Characteristics of Ranked Data..................................	251
Table 7.3:	Social Impacts Ranked by Mean Score....................................	255
Table 7.4:	Social Impact Index by Village Occupation................................	266
Table 7.5:	Severity Class-Impact Intensity Conversion Table.........................	266
Table 7.6:	Impacts Ranked by Social Impact Index....................................	267
Table 7A.1:	Results of Ranking Game for Gummaladabba Village....................	272
Table 7B.1:	Summary Statistics of Surveyed Creek-Based Villages..................	273
Table 7B.2:	Percent of Village Sample Claiming Impact as Problematic............	273
Table 7C.1:	Summary of Ranked Impact Data by Location.............................	274
Table 7E.1	Simulation Experiments on Theta...	278
Table 7E.2	Selected Methods to Rank Impacts...	280

LIST OF TABLES (CONTINUED)

Table 8.0:	A Roster of Explanatory Variables...	293
Table 8A.1	Factors Explaining Well Water Salinity Problems........................	305
Table 8A.2:	Factors Explaining Agricultural Land Salinity Problems................	306
Table 8A.3:	Factors Explaining Blocked Access Problems..............................	307
Table 8A.4:	Factors Explaining Fodder & Fuelwood Collection Problems..........	308
Table 8A.5:	Factors Explaining Unemployment Problems..............................	309
Table 8A.6:	Factors Explaining Health Problems..	310
Table 8C.1:	Primary Assets Owned by Fishing Communities in Andhra Pradesh..	314
Table 8D.1:	Marginal Effects of Significant Ordered Probit Coefficients...........	315

LIST OF FIGURES

Figure 1.0:	World Production of Shrimp (1980-1996)................................	16
Figure 1.1:	Global Cultured Shrimp Production (1985-1994)........................	17
Figure 2.0:	Map of India, Andhra Pradesh and Nellore District......................	55
Figure 2.1:	Location of Surveyed Villages Along the Kandaleru River...........	68
Figure 3.0:	Capital-Labour Input Proportions & Culture Intensity.................	97
Figure 4.0:	Total On-Farm Labour Requirements..	138
Figure II:	A Tree of Techniques to Model Productive Efficiency.................	150
Figure 5.0:	A Representation of the Deterministic and Stochastic Frontiers........	159
Figure 5.1:	A Flow Diagram for Model Selection....................................	166
Figure 6.0:	Farrell Efficiency Measures...	205
Figure 6.1:	Decomposition of Pure Technical Efficiency and Scale Efficiency....	209
Figure 6.2:	Farm Size-Efficiency Relationship..	218
Figure 7E.1:	The Intensity of Six Impacts (Simulations on Theta)....................	279

To my parents,

G.P. & Lalita Patil

&

To Theirs...

A Note of Thanks...

Investigating shrimp farming in India for my doctoral work seems a natural consequence of my interests in development economics, the environment (especially coastal areas), rural peoples, travelling and the Indian sub-continent. During my extensive travels throughout Asia's many coastal countries after college, I first noticed a shift in the daily activity of inhabitants of several coastal villages—from fishing to a mixture of fishing and fish (shrimp) farming. Moreover, shrimp is my favourite food. However, there are several people and institutions whose support enabled me to combine my interests and pursue an investigation of shrimp.

I would like to thank Professor the Lord Desai for his supervision and Yougesh Khatri for his invaluable assistance in helping me navigate through production theory and its application. The data for this research was collected with the partial support of the Rajiv Gandhi Foundation, New Delhi, India while I was serving as the 1996-1997 Rajiv Gandhi Foundation Scholar. Moreover, it could not have been successfully completed without the invaluable assistance, insights and shared vision of Dr. M. Krishnan, the Senior Fisheries Economist of India's Central Institute for Brackishwater Aquaculture. I thank Jenny Piesse for helping me obtain the necessary computer software to analyse my data.

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Part I

Assessing Shrimp Farming's Growth & Development

Introduction

The rising demand for shrimp in Japan, the United States, and Western Europe has fostered dramatic growth in Asian brackishwater shrimp farming. Since 1990 this sector has annually captured over 80 percent of the world market and has generated over US$20.8 billion in foreign exchange for the region (Csavas 1995: 73). Amidst its economic boom, intensive brackishwater shrimp culture is creating concern over its degradation of the environment (Flaherty and Karnjanakesorn, 1995; APO, 1995: 6; Southgate and Whitaker, 1992; Stonich, 1992; Doumenge, 1990) and its marginalization of local people from coastal resources (Sebastiani et al, 1994; Baily, 1988). While governments continue to provide means for urban-based investors and large corporations to develop large-scale shrimp culture along Asia's coastline, the markets have yet to incorporate the environmental and social costs of this economic activity. Instead, the environmental and social costs associated with shrimp farming's negative externalities are borne by the rural poor, who rely on natural coastal resources for their livelihood.

Over the past two years, India has received more attention than its equally prolific neighbours with respect to shrimp farming. This is a result of the December 1996 Supreme Court Ban on this sector. With India's several thousand kilometer long coastline predominantly settled by rural fishers and farmers, the fate of this environmentally fragile zone and its inhabitants has been put into question by the rapid development of shrimp culture (SC Notification, 1996). As in the rest of Asia, Indian shrimp aquaculture has been promoted by governmental bodies and international and multilateral lending agencies as a means of generating foreign exchange through exports and enhancing supplementary income generating opportunities for impoverished small scale fisherman through job creation (World Bank, 1986; Flaherty and Karnjanakesorn, 1995: 27-8). Donor agencies such as the World Bank and Asian

Development Bank have approved over US$500 million in loans since 1986 to develop approximately 1.5 million hectares of public coastal wetlands[1] and over 122,000 hectares of coastal land for Indian shrimp aquaculture (World Bank, 1986; Sukumaran and Devraj, 1995).

The role that brackishwater shrimp aquaculture development is playing on India's economy is substantial. Indian marine exports were the second largest foreign exchange earner in 1994-1995 primarily because of high value shrimp exports to Japan, Europe and the United States. Shrimp (captured and cultured) constituted 70.2 percent of total Indian marine export value in 1994-1995 which slipped slightly to 67.3 percent in 1995-1996 due to fluctuations in export prices.

Currently, 58,376 hectares of coastal land throughout India's maritime states are estimated to be annually producing over 35,000 metric tons of shrimp (MPEDA, 1996). Private entrepreneurs are also rapidly entering the industry. In two south-eastern coastal states, Andhra Pradesh and Tamil Nadu, over 180 privately financed semi-intensive shrimp aquaculture farms have been constructed in the past few years (NEERI Report, 1996). According to the latest export statistics, farmed shrimp alone generated over 1,500 Crore Rupees[2] for the Indian economy in 1995-1996 (MPEDA, 1996). The questions remains, at what cost and to whom?

The first four chapters of this dissertation are concerned with assessing the growth and development of shrimp farming. In this context, both the positive benefits and negative externalities of shrimp farming are discussed. However, our primary focus is on the negative externalities of brackishwater aquaculture as several claims are made in the literature denouncing this sector., but with little empirical support. While the focus on negative externalities is the mostly widely discussed topic in the shrimp farming debate, it is the least critically assessed.

Chapter One provides an overview of Asian shrimp farming and its impacts. The productive capacity of the most prolific shrimp farming nations are discussed and some of the better known impacts (both positive and negative) are reviewed. Moreover, this chapter sets out the research objectives and highlights

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[1] Public coastal wetlands in India have traditionally provided a large source of consumption goods such as fish and other brackish water foods for the subsistence poor who are landless and own few assets.

[2] One *crore* Rupees is exactly 10 million Indian Rupees.

the contributions of the dissertation. Chapter Two presents a discussion of the methodology used to survey over 500 Kandlaeru shrimp farms and inhabitants of twenty-six rural and coastal villages located adjacent to them. Chapter Three analyses the growth and development of shrimp farming along the Kandaleru river—one of the most prolific shrimp farming areas in India. Finally, Chapter Four examines the impact of the changing land use pattern (allegedly caused by shrimp farming's growth in coastal areas) on agricultural labour.

Chapter 1

An Overview of Asian Shrimp Farming & Its Impacts

1.0 Introduction

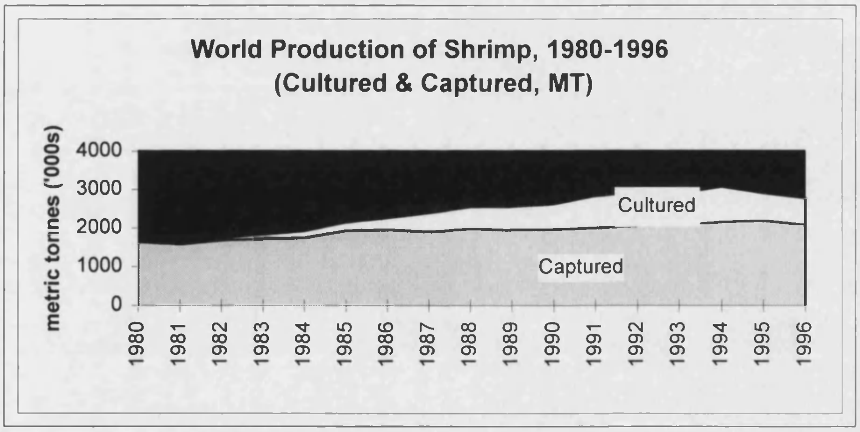
While traditional methods of cultivating shrimp have existed for centuries, several dozen maritime developing countries have been supporting intensive shrimp farming over the past decade. Heralded as a means of earning foreign receipts from exports and in creating jobs, the shrimp farming sector has been left virtually unregulated. Today, however, domestic and international pressure is mounting on countries exporting cultivated shrimp. Environmental activists, international NGOs, international organisations and the industry itself have called for international efforts to improve shrimp farming technology and to ensure its sustainable development. This is particularly true as the global shrimp farming sector has faced several set backs over the past several years as a result of a growing awareness of its negative environmental and social impacts.

This chapter presents an overview of global shrimp farming and its impacts. Section 1.1 discusses the rapid rise in global farmed shrimp production and compares this to the production of captured shrimp. Section 1.2 explains the process of farming shrimp. Section 1.3 discusses the environmental and socio-economic impacts allegedly caused by shrimp farming. Section 1.4 moves away from the world stage and discusses the growth and development of Indian shrimp farming from 1900 to 1998. Section 1.5 presents the three primary research objectives of this dissertation. Finally, the contributions of this research are discussed in Section 1.6.

1.1 Overview of Shrimp Farming

The importance of cultured shrimp in world consumption has grown significantly over the past eighteen years. In 1980 cultured shrimp made up less than 3 percent of the market in terms of volume. Today, farmed shrimp makes up approximately 25 percent of annual global production (see *Figure 1.0*). In the past ten years alone, global shrimp aquaculture production has grown over 400 percent, from 213,017 metric tons in 1985 to 931,788 metric tons in 1995 (FAO, 1996). In 1996, global farmed shrimp production declined as a result of widespread disease which led to significant crop loss. 1997 shrimp production will most likely show an increase from 1996 levels as a result of an overall successful global harvest (Minnesota Commodity Exchange Board, 1998).

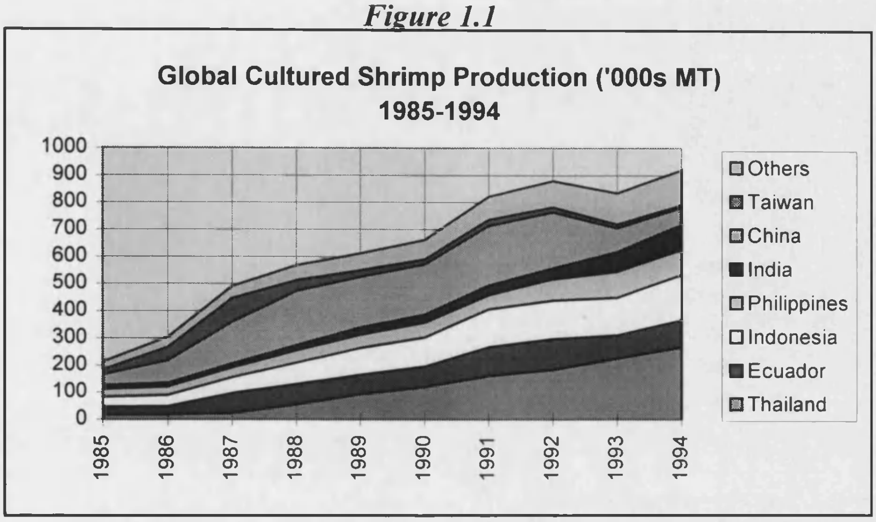
Figure 1.0



Source: FAO Aquaculture Statistics, 1996

According to FAO's most recent aquaculture statistics, the major global producers of farmed shrimp are Thailand, Indonesia, India, China, Philippines, Ecuador, and Taiwan (see *Figure 1.1*). These seven countries contributed approximately 86 percent of the global cultured harvest in 1995. The remaining 14 percent came mostly from a half dozen South American countries including Belize, Mexico, Nicaragua, Panama, Venezuela and Colombia. The Asian region has been by far the largest shrimp producing region in the world, capturing over 80 percent of the global market (FAO, 1996).

Figure 1.1



Source: FAO Aquaculture Statistics, 1996

The main species of cultured shrimp are classified as *penaeid* and include the Black Tiger, Kuruma, Whiteleg, Blue, Brown Tiger, Banana, and Indian White varieties. However, the Black Tiger variety are known to command the highest overall price globally and seem to be the cultured species of preference.[1] The average nominal per kilogram price for Black Tiger shrimp between 1993 and 1997 was approximately $US 13.85 (INFOFISH Trade News, 1996).

1.2 Brackishwater Shrimp Aquaculture

1.2.1 The Process of Farming Shrimp

The infrastructure needed to support basic shrimp culture in rural coastal areas is minimal. Shrimp farmers are usually unrestricted in their search for a viable locality for production. Two geographic constraints include close access to the sea or brackishwater/estuarian areas and preparing ponds on soils conducive to producing successful harvests, namely clay. Shrimp farmers must purchase or lease privately owned land from rural land owners or from the government. In many cases, this involves purchasing mangrove forest areas, purchasing or leasing agricultural land and/or wasteland. Government and public access land is also encroached for shrimp farming. Once purchased or leased and land is dug to form ponds, usually one hectare in size. Next, the pond is filled with water pumped from the sea or the adjacent brackishwater body. Upon completion of the pond, shrimp fry are purchased from local hatcheries or from village agents and stocked. The fry are fed with purchased inputs from local feed mills or locally produced feed. Several months later the shrimp are harvested, packed in ice and sent to a peeling shed where they are block frozen for export.

The main shrimp species cultured in India are the black tiger shrimp *(P. monodon)* and white shrimp *(P. indicus)* with freshwater shrimp cultured in small quantities (Sukumaran and Devraj, 1995: 310. The life cycle of the penaeid shrimp is characterised by offshore spawning, migration of post-larval or juvenile shrimp to estuaries, juvenile growth in brackish water areas of inshore estuaries, and finally a return as young adults to the spawning grounds. Shrimp culture, by contrast, is the method of raising shrimp in a controlled environment. A more technical description is "intervention in shrimp fisheries, involving physical control of the organism at some point of the life cycle other than at harvest" (FAO, 1984). This intervention can be minimal (i.e. catching shrimp seed stock in coastal lagoons and raising them in natural ponds that eventually lead to increased harvests) or maximal (i.e. spawning and growing shrimp in an artificial, closed system environment).

There are predominantly four shrimp farming or *culture* techniques used throughout the world: extensive, modified-extensive, semi-intensive, and intensive methods that yield on average 500 kilograms, 800 kilograms 2,000 kilograms and between 2,000-10,000 kilograms per water spread hectare respectively (Hirasawa, 1995: 218). In traditional paddy-cum-shrimp farming all the nutritional requirements for farming shrimp are derived from the surrounding natural ecosystem with no conscious human manipulation in the feeding process. Traditional shrimp farming is therefore not considered a culture technique according to the strict FAO (1984) definition (CIBA, 1997). In extensive, modified-extensive and semi-intensive culture the natural carrying capacity of the shrimp farm is enhanced by employing intentional fertilisation and supplemental feeding techniques to increase yields. In intensive culture methods all the nutritional requirements for raising shrimp are met from sources

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[1] According to the USA Commodities & Grain Exchange located in Minnesota.

external to the natural ecosystem. Once shrimp are raised to commercial size, they are sold to local traders who transport them to port cities and sell the harvest to urban agents (BOBP, 1996). The agents sell the shrimp to packaging companies who export the shrimp either frozen or fresh for international consumption, mostly to Japan, the United States and Europe.

1.2.2 Industry Status

Because of its need for ancillary services such as seed hatcheries, feed mills, ice plants, and processing plants, the shrimp farming sector in conjunction with ancillary services can be classified as an industry. While the shrimp farming sector can be defined as *the collection of shrimp farms involved in the actual process of culturing shrimp,* the shrimp farming industry refers to the *shrimp farm sector plus the ancillary services that support the cyclical culture operation of shrimp farms.* The distinction between the shrimp farm sector and the shrimp farm industry as defined above is made in this thesis.[2]

1.3 Environmental & Socio-economic Impacts

Since the sector's economic boom in the mid-1980s, there has been a growing body of literature on the social and environmental impacts of shrimp farming. Most of the literature, however, remains uncritical in its discussion of social impacts and sparse in its assessment of the environmental impacts (Barraclough and Finger-Stich, 1997: 11-13). One partial explanation is that in many of the case studies, the authors seldom distinguish between the different agents involved in shrimp farming and how exactly they are affected. Oftentimes, conclusions are based on generalisations and mostly anecdotal evidence. This thesis both models and measures the socio-economic and environmental impacts of brackishwater shrimp aquaculture on rural producers in Nellore District, a

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[2] These definitions are provided by the author since there are no standard definitions marking the difference between the shrimp farming sector and the shrimp farming industry. Some author's such as Hempel and Winther (1996) point out that there is a shrimp farming industry, but do not explain why it should receive industry status.

major shrimp producing region in south-eastern India. However, before presenting the case study on Nellore District, the concerns raised and conclusions drawn by authors of other studies are presented.

Specifically, there is a growing literature claiming that the shrimp farming sector is responsible for the degradation of the environment and for the changing face of the rural landscape and the labour force. Much of the current literature focuses on shrimp farming's negative impacts. In the following section the existing literature on the environmental and social impacts is surveyed. Moreover, some of the lesser known positive benefits of shrimp farming are discussed.

1.3.1 Shrimp Disease & General Mismanagement

The type of culture method employed or production technology used is allegedly linked to the level of profitability and the nature of negative externalities. Ideally, the more intensive the production process, the greater the output and profit. However, experts agree that this occurs at a greater risk to the environment and to those people who rely on coastal resources for their source of livelihood (Hiraswara, 1995: 218). The possibility of catastrophes on national scale are well documented in the case of Taiwan's 1987-88, China's 1989-90, and Ecuador's 1988-89 intensive shrimp farming disasters where annual production fell from 90,000 Mt. to 45,000 Mt., 199,000 Mt. to 150,000 Mt., and 70,000 Mt. to 55,000 Mt. respectively (Chong 1995: 224). In the Taiwanese example, the shrimp farming industry throughout the country collapsed with production dropping over 50 percent (Chen, 1990). By 1989, the shrimp farming sector in Taiwan was essentially defunct. According to the latest statistics, Taiwan is an insignificant player in the Asian region's dominance of global shrimp production.

These falls in production were allegedly due to unsustainable intensive or " superintensive" culture methods which sought to boost production by initiating higher stocking densities and greater feed inputs holding pond size constant. The process of intensification produced cramped culture grounds, water pollution, and disease that destroyed entire harvests (Iwama, 1991: 194-202; Moore, 1989).

Like a domino effect, effluent discharge rife with disease from one pond infiltrated downstream ponds through water intake from common waterways. The longer term effects have been higher production costs, water pollution, declining groundwater tables, and lingering disease (Moore, 1989).

In India, shrimp aquaculture faces an additional challenge on the production side since biological and technical knowledge of its culture is limited and infrequently reaches the entrepreneur (Patil and Krishnan, 1997b). The industry is not only vulnerable to changing economic conditions such as the fluctuating international price for shrimp, but also to the outbreak of disease. In order to determine the optimal stocking rates, feed formulas, and disease treatment, farmers often rely on trial and error or imported knowledge that is not necessarily applicable to Indian climate and conditions (Patil and Krishnan, 1997b). Imported feed and high stocking densities (the two inputs necessary for intensive culture) are allegedly responsible for water pollution and shrimp disease (APO, 1995). As the quantity of imported shrimp feed has risen from 121 tonnes in 1988 to 6,243 tonnes in 1994 (MPEDA, Cochin quoted in Nandeesha 1995: 228) there is growing concern of ecological disasters similar to those exhibited in Taiwan. Nonetheless, the opportunity of generating large profits encourages aquaculture expansion in India and throughout the Asian region.

The drop in market share once controlled by Taiwan has enabled new producing countries with undeveloped coastlines such as the Philippines, China, Indonesia, Thailand, and India) to fill the void (Csavas 1995: 123).[3] However, many similar environmental problems faced by Taiwan's shrimp farmers are now surfacing in these countries (Flaherty and Karnjanakesorn, 1995; Iwama, 1991). In addition, there is increasing concern over the socio-economic impacts of shrimp production on coastal inhabitants of poorer countries.

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[3] In 1987 Taiwan controlled over 35 percent of Asia's total output and 31 percent of world production (FAO Aquaculture Statistics, 1996).

1.3.2 Local Negative Environmental & Socio-economic Impacts

The environmental and socio-economic impacts arising from shrimp farming are inexorably linked. Social impacts may include the redistribution of wealth, the changing nature of resource rights to traditionally used public lands, human rights issues, changes in employment and the overall social structure of communities (Hempel & Winther, 1997; Claridge, 1996).

Many of the negative socio-economic impacts of shrimp farming arise as a result of degradation of the natural environment. There have been several concerns raised over the environmental implications of shrimp farming in coastal areas. Specifically, shrimp farmers have been accused of mangrove forest clearing, ground water depletion and/or salinization, well water and agricultural land salinity as a result of pond bottom seepage and discharge of polluted effluent into ecosystems. They have also shouldered the blame for the decline in wild stocks as a result of excessive stocking. The severity of each environmental externality depends on the magnitude of the impact on the ecosystem (i.e. its impact on flora and fauna) and ultimately on human populations. Many of the environmental impacts have both direct and indirect ways of affecting the overall well-being of local communities competing for the same natural resources as shrimp farmers. This discussion first traces the recognised linkages between the environmental problems allegedly caused by shrimp farming and the alleged impacts on rural inhabitants. This is followed by a discussion of some of the more well known positive socio-economic impacts, in section 1.3.3.

Mangrove Forest Conversion

Mangrove forests are an important component of coastal ecosystems in tropical and subtropical regions of the world. They grow prolifically in tidal estuaries and salt marshes along the coast and provide tremendous benefits to indigenous peoples inhabiting these areas. Specifically in India, mangrove forests are used by local people as a source of firewood, construction material, income generating activities and own consumption such as fishing (MSSF, 1996). Mangroves are also a well known source of rich bio-diversity. They serve as a nurse-bed for fish and crustaceans that also serve as a natural protection zone against flooding and typhoons. With their destruction, these benefits naturally disappear.

There is a growing literature suggesting that mangrove clearing is a consequence of urbanisation, commercial logging, unrestricted fuelwood collection from coastal inhabitants, charcoal making, agriculture, fish pond construction, salt flat development and industrial development in addition to shrimp farming (Gujja & Finger-Stich, 1995:29). While it is clear that shrimp farming is not the only cause of global mangrove forest depletion, it is believed to be one major player. There is, however, a debate taking place over shrimp farming's contribution to global mangrove forest loss. Even at the individual country level there is much dispute over the proportion of mangrove forest loss as a direct result of shrimp farming.

Phillips et al (1993:174-175) estimate that over 765,500 hectares of the world's mangroves have been cleared for shrimp and fish culture with over 80 percent of global conversion occurring in Asia. The degree to which mangroves are being cleared for the purpose of shrimp farming, however, varies between countries. The FAO estimates that 34 percent of Thailand's shrimp farming area was primarily mangrove forest areas ten years earlier (NACA, 1994: 15). In the Philippines between 50 to 60 percent of mangrove deforestation is attributed to shrimp and fish culture (FAO/NACA, 1994; Pollnac, 1992:17). In peninsular Malaysia, Ong (1982) reports that between 20 to 25 percent of mangrove regions was earmarked for shrimp farming. The largest remaining mangrove in the world, the Sundarbans in India and Bangladesh are also believed to have been have been systematically denuded as a result of shrimp farming. FAO/NACA (1994:26) report that approximately 35,000 hectares of shrimp farms have replaced vast stretches of West Bengal's mangrove areas. Similarly, on the Bangladeshi side, the Department of Forests claim 9,250 hectares of mangroves have been cleared for shrimp farming (Sultana, 1994:14).

While shrimp farming is blamed for destroying large tracts of mangrove areas, the data available are often incomplete and contradictory (Hempel and

Winters, 1997:47). Local and regional studies are often generalised as representative of the national situation. In addition, some studies have found that mangrove forest areas are not ideal sites for shrimp culture. This has led to shrimp entrepreneurs staying away from mangrove areas. Boyd (1997) for example suggests that the highly acidic soil and large amounts of organic matter found on mangrove cleared farms make these areas less than ideal for culturing shrimp. This fact is also reported by farmers in at least two countries, Thailand and India.[4] Nonetheless, without readily available satellite imagery, it is difficult to pin point exactly what proportion of mangroves are denuded as a result of shrimp culture. The expert literature does suggest, however, that the remaining mangroves must be preserved.

Ground Water Depletion

Water is a key input in shrimp farming and salinity levels of 15 to 20 parts per thousand (ppt) are thought to be ideal. While traditional aquaculture systems rely on natural tidal action to ensure the pond water is appropriately oxygenated, more intensive systems require a mix of pumped water from ground water reservoirs, the sea or brackishwater bodies to make sure the appropriate salinity level is reached and not breached.

Competition for groundwater from different sectors has shored up with the advent of intensive shrimp farming. Before shrimp farming, ground water was pumped for irrigating agricultural land and for domestic consumption by local inhabitants. Although there has been concern in many parts of the world over possible depletion of ground water in drier seasons, for the most part, the resource has been used adequately.[5] The entry of shrimp farming is reported in some studies, however, to have tipped this balance.

A case study of the Rancot district in Thailand reports that 33 cubic meters of freshwater are pumped per day for each metric ton of shrimp produced.

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[4] Based on comments made during the ADB Seminar on Shrimp Farming and the Environment on September 15-16, 1997 in Manila.

[5] This is presently true of India according to the Brackishwater Fish Farmers' Development Authority in Nellore city, India.

The groundwater table dropped 4 meters between 1989 and 1991 as a result of excessive pumping for shrimp farming (NACA, 1994: 46). In areas of highly concentrated intensive shrimp farms such as in the Philippines and Taiwan, depleted water tables as a result of excessive pumping led to land sinking by three meters (Chiang and Kuo, quoted in Barraclough and Finger-Stich, 1995). The Indian Supreme Court after weighing all the available evidence concluded that competition with shrimp farmers for groundwater result in loss of water supplies for the cultivation of rice and other vital agricultural crops (Supreme Court Notification, 1996:12). Boyd (1997:5), however reports that while farmers outside Asia seldom pump groundwater to fill shrimp ponds, the practice is even rare in Asia. This, however, is a point of view shared by a minority group of scholars. They argue that in coastal areas fresh drinking water is becoming an increasingly scarce resource, not because of the excessive pumping of ground water reserves by shrimp and rice farming, but increasingly because of water pollution. This is discussed next.

Water Pollution

Shrimp farming has allegedly been responsible for two types of water pollution, (i) saltwater intrusion into groundwater reservoirs, and (ii) pollution of near-shore waters and estuaries from high concentrations of biological and chemical effluent discharge from shrimp farms. Saltwater intrusion into groundwater is often a result of water seepage through the pond bottom. The consequence of increasingly saline water tables is enormous for coastal inhabitants for the simple reason that water drawn from village wells becomes unusable for human and animal consumption. The lack of fresh water in many villages adjacent to shrimp farming clusters has several socio-economic impacts.[6]

The use of organic fertilisers, drugs and antibiotics and chemicals while increasing the growth prospects of shrimp, have also made the internal pond ecosystem less stable. Nitrogen and phosphorous based fertilisers are used to

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[6] .These are discussed in Chapter Seven.

stimulate phytoplankton growth in semi-intensive and intensive shrimp ponds. In addition, unconsumed feed inputs and faecal matter increase the organic and nutrient content of the pond water. Antibiotics are used to protect shrimp from disease and mortality. Chemicals are added to ponds for disease chemotherapy, pest control, disinfection and growth promotion. This mix of additives used to prevent disease and promote growth have several environmental consequences to both the internal (pond) and external (coastal waters) ecosystems.

The possible consequences of pond water discharge into coastal waters depend on the ecosystem's capacity to assimilate its high organic load. The Indian Central Pollution Control Board estimates that about 2.37 million cubic meters of shrimp farm effluent are discharged each day in eastern India. This amounts to approximately 15,000 litres of effluent per kilogram of shrimp produced (Gujja, 1997:12). The negative externalities known to affect coastal waters as a result of pond water discharge include: siltation, eutrophication, oxygen depletion, toxicity and disease outbreaks (Dierberg and Kiattisimkul, 1996). Excessive use of drugs, antibiotics and medicated feed are known to transfer to wild fish species causing genetic disorders (Chua,1993). There have aslo been several claims that general public health is adversely affected due to polluted discharge water.

Health Problems

Chemicals used in shrimp farming while only mildly toxic, can also have severe effects on the environment and people working around them. Boyd (1997) gives an account of places where shrimp farm discharge water has polluted coastal areas and human populations. Exposure to polluted discharge water can put local inhabitants at risk. Specifically, several field reports on the Indian situation suggest that fisher folk are most likely to suffer from minor skin irritation (Patil & Krishnan, 1997). Other reports allege more serious health risks including scabies and fever (Suresh Committee, 1996).

Agricultural Land Salinity

In addition to raising the salinity level of groundwater reservoirs, seepage of brackish pond water into adjacent agricultural fields is allegedly a growing problem. Studies conducted in Thailand (Flaherty & Karnjanakesorn, 1995), Bangladesh (FFI, 1997) and India (Patil & Krishnan, 1997) report damaged crops as a result of salt water intrusion into agricultural land. As a result, there are growing conflicts between rice and shrimp farmers.

Declining Wild Stocks

Shrimp fry collected from estuaries to meet the growing demand for stocking ponds have provided coastal inhabitants, mainly women and children with an opportunity to supplement household income. With shrimp farmers paying out Rs. 0.10 per seed[7], the number of wild shrimp fry available to grow to maturity is believed to have declined (Algaraswamy, 1995:15). This is also a problem for fishermen who no longer enjoy handsome profits from shrimp capture. Afterall, shrimp captured from the sea at maturity and sold at the local market are more valuable to a fishing household than seed sales (BOBP, 1996). Shrimp fry collection has also led to the large-scale destruction of shrimp fry by-catch. Banerjee and Singh (1993) report that the by-catch can often consist of over 60 species of baby fish, less valuable penaeid prawns, sergestid, palaemonid prawns and crabs which are destroyed while capturing more popular species of shrimp fry.

Shrimp farming has also been accused of being an energy intensive method of producing food. This means that other edible species are used in cultivating shrimp. Pelleted shrimp feed contains between 25 percent and 50 percent fish meal (Nandeesha, 1995:218). Fish meal is one of the main ingredients in shrimp feed and can account for 50 percent of the total cost (Gujja, 1997:12). It is estimated that shrimp are fed three times their harvested weight

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[7] In the Kandaleru region, wild seed command a price of up to Indian Rs. 0.25 per piece during the peak season.

(Patil & KAA Database, 1997b). They are believed to convert on average only 17 percent of the consumed feed into edible flesh (Gujja, 1997:12).

Blocked Access

Other problems directly faced by coastal inhabitants include denial of access to temples, burial grounds, open toilet areas and grazing land (Mohan, 1996:7). In addition, fishers in India complain that they are unable to reach their boats at the beach. This is a consequence of shrimp farm development which blocks access between village communities and free access areas.

Land Conversion & Employment

There is considerable agreement in the literature that shrimp farming is displacing traditional employment opportunities for coastal inhabitants. Empirical studies conducted to prove or disprove this claim directly, however, remain sparse. Three categories of studies discuss this issue. Each one is discussed in turn.

The first series of studies conclude that shrimp farming requires far less labour inputs than traditional agriculture per unit area (especially paddy cultivation). Islam (1992) reports that in the Sarkira sub-division of Khulna District, Bangladesh, while 50 workers are needed to cultivate 100 acres of rice, only five workers are needed to culture shrimp for the same area. Hanning's (1986) study of Java, Indonesia reports that a two hectare shrimp pond requires thirty days of family labour and sixty days of hired labour whereas thirty-two days of family labour and 120 days of hired labour are needed to cultivate rice for the same area of land. A second Indonesian study concludes that rice production employs an average of 76 workdays per hectare per crop while only twenty-six workdays per hectare per crop are required for semi-intensive shrimp farming (McCoy cited in Baily and Skladany, 1991). In India, Subramanian (1994:70 cited in Clay (1996:108)) reports that local rice farmers claim that during a four month crop season, one hectare of land employs 60 women and 15 men. Shrimp farming, they argue is not so labour intensive. Although they allude to the popular belief that shrimp farming is displacing traditional agricultural employment opportunities for local inhabitants these studies only compare the employment levels in two different types of crop cultivation, namely shrimp and rice. PREPARE (1995:2) suggest that shrimp farming provides direct employment for only two persons per hectare in Andhra Pradesh.

A second series of studies in the literature, makes the claim that when agricultural land is converted to shrimp ponds there is a direct loss of employment opportunities for local labour. A study by the Centre for Communication and Development concludes that extensive shrimp production on 670 hectares of land in West Bengal employed one third less labour than when the same area was used for rice paddy cultivation (undated: 25). These studies are perhaps the most informative, but remain scarce in the literature.

A third series of studies suggest that the type of employment generated by shrimp farming is often not available to local inhabitants (Snedaker et al,. 1986). This literature suggests that the on-farm jobs generated by the shrimp farming sector are mostly filled by labour from outside the shrimp farming region. For example, a CCD (undated) study concludes that about half of the West Bengal shrimp farming region's labour force is recruited from outside the farming region and without local ties because they are thought to be more responsible. However, a FAO/NACA (1994b:58) study in West Bengal suggests that on-farm jobs such as pond preparation and management are locally filled in addition to those off-farm jobs in shrimp processing. The study also suggests that 33,000 hectares of shrimp ponds translate to 50,000 off-farm part time shrimp fry collection jobs for local people. Studies by Baud (1992) and Banerjee (1992), however, suggest that most off-farm processing jobs are filled by women from outside the shrimp farming region and mostly from the Indian state of Kerela. Whereas the literature does suggest that both on and off farm employment can benefit both local and outside labour, case studies going into any further detail are lacking.

A similar debate exists as to whether the owners of production are from the local area or from outside. The Bangladesh Department of Fisheries estimates that approximately 75 percent of shrimp farmers operating in Khulna and Satkhira districts during the early 1990s were non natives of these coastal districts. Similarly, in a study of several Bangladeshi coastal villages, only 10 of 300 households obtained leases for shrimp farming (Sultana, 1994: 10-11). Sultana (1994) concludes that shrimp farming is beyond the reach for most local farmers but does not give reasons why.

The alarm raised by these studies may be slightly misleading. Whereas the literature does correctly suggest that rice farming employs a greater labour force than shrimp farming over the same unit land area, these studies do not prove that shrimp farming is actually displacing the traditional labour force. Instead, they conclude that *if* shrimp aquaculture were to replace traditional agricultural crops, then there would be the possibility of unemployment. The few case studies analysing the change in employment patterns due to the conversion of agricultural land to shrimp ponds are perhaps the most illuminating. These studies correctly point out the existing realities of employment changes due to conversion. They do not, however, indicate the total social costs of these externalities which would include any benefits accruing to the labour force such as a higher wage rate gained from employment in shrimp farming. Additionally, these studies suggest that entire fertile agricultural areas are being converted to shrimp farms, however, with little supporting data. The extent to which agricultural land is converted to shrimp farming most likely varies significantly between regions within a particular country and among countries.

Nellore District is considered one of India's fastest growing shrimp farming regions. It is within the detailed case study of this district and particularly the economic activity taking place along one brackishwater body, the Kandaleru Creek that we are able to discuss the conjectures raised in the literature and place them within a solid analytical framework with data analysis.

1.3.3 Benefits Accrued from Shrimp Cultivation

The literature is abundant with criticisms of the practice of shrimp farming as discussed in the previous section. Less discussed in the literature are the benefits accrued from shrimp farming. Outside foreign exchange earnings from shrimp export and indirect "trickle down effects" associated with many export-led sectors, little documentation and discussion exists on the benefits of shrimp aquaculture. Next, several alleged benefits discussed in the literature are briefly reviewed. These include foreign exchange earnings through shrimp export, the growth and development of ancillary services supporting the shrimp farm sector, generation of off-farm employment, general gains in land productivity and an increased value of land and on-farm employment generated as a result of this sector's growth and development.[8]

Foreign Exchange Through Trade

Shrimp culture is primarily an export-led sector. Shrimp are exported to developed countries as a luxury food, earning foreign exchange for the developing country. Still dominated by the Asian region, shrimp culture is gaining momentum in several Latin American countries and more recently, in Africa (FAO/World Bank, 1997). As mentioned before, cultured shrimp exports generate approximately $20 billion for the Asian region alone. Indian cultured shrimp exports in 1996 were valued at approximately US$ 430 million in current prices (MPEDA, 1997). Cultured shrimp exports are estimated to have generated between US$ 404 million to US$ 808 million for Bangladesh (Sharif et al., 1996:153). According to Hempel and Winther's (1997:24) World Bank commissioned study, country revenues from cultured shrimp exports range from US$ 300 million to US$ 1 billion.

Ancillary Services & Off-farm Employment

Ancillary services provide essential support services to the shrimp farming sector such as seed hatcheries, feed mills, ice plants, peeling sheds and processing plants. The development of each support service is partially responsible for the boom of this sector. Similarly, the strength of the shrimp

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[8] This research, however, does not attempt to measure the costs and benefits of shrimp farming.

farming sector has encouraged the growth and development of supporting services. This has translated into jobs.

There is little discussion in the literature as to the role of ancillary services in shrimp farming. Only a few literature surveys mention the study of ancillary services as an area worth exploring.[9] This research contends that there are several benefits accrued locally from ancillary services. Most prevalent, however, are the off-farm employment opportunities generated. This research particularly focuses on the growth of off-farm employment as a result of the introduction, growth and development of ancillary services.

An Increase in Land Productivity and Value

Land previously defined as "wasteland" and left idle is now being developed for shrimp culture. Moreover, since the advent of shrimp farming, coastal land prices have allegedly risen dramatically in Thailand, India, Indonesia and other shrimp farming nations (Barraclough and Finger-Stich, 1996).

On-Farm Employment

Non-traditional shrimp farming is believed to be highly capital intensive in many parts of Asia. However, while it is clear that shrimp farming does employ local inhabitants, most studies suggest that as compared to traditional agriculture, employment in shrimp farming is far less (see Section 1.3.2: *land conversion & employment*). Nonetheless, if previously unproductive land is converted to productive use, it can be assumed that there are significant employment gains. Moreover, this does not conflict with the belief that shrimp farming displaces agricultural labour.

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[9] For example, Hempel and Winthers (1997) and Clay (1996) mention this.

Development of Aquaculture Associations

The rapid growth of shrimp farming associations throughout the world is quite remarkable, but perhaps not surprising. Currently, these associations are taking on a more political role. This is a result of the mounting pressure placed on shrimp farmers by local action groups agitating against the sector. Shrimp farm associations could provide a forum to discuss best farm management practices. They could serve as forums to discuss and share technical knowledge to minimise disease and negative environmental and social impacts. Moreover, they could provide regulatory agencies with a forum with which to help guide the sector along sustainable lines.

1.4 Indian Shrimp Farming (1900-1998)

1.4.0 Traditional Shrimp Farming

For centuries fisher-folk in coastal India have engaged in traditional integrated rice-cum-shrimp farming, specifically in the *Pokkali* rice fields of Kerala and the *Sunderbands* of West Bengal (Sukumaran and Devraj, 1995:301). This integrated farming technique roughly follows a seasonal, four period cycle. In the first period, rice is planted. In the second period rice is harvested. The bunds used to keep brackish estuarian river water from flooding the rice field are broken, allowing shrimp fry and smaller species of fish to enter the farm with the water flow. The bunds are then repaired, creating a pond-like environment. The shrimp fry are naturally fed by the rice grass and natural fertilisers in the soil. They grow for several months to maturity. In the third period, the shrimp are harvested. The harvest is small, approximately 50 to 75 kilograms per hectare. The bunds are then once again broken and the pond water flows black into the brackishwater river. In the fourth period, the monsoon rains wash away any excess salinity from the top soil of the farm. Rice is planted, and the cycle begins anew. This traditional system of shrimp aquaculture does not use processed feed, chemicals, antibiotics or any other unnatural inputs. It simply makes use of natural tidal action for capturing wild shrimp fry in the make-shift pond and for water exchange. Experts agree that it is ecologically and socially sustainable (APO, 1995).

1.4.1 The Blue Revolution

The method used to culture shrimp began to change in the early 1980s. Global supply of shrimp was fuelled by the growing markets of Japan, USA and Europe. In the United States, for example, shrimp were marketed as a "low fat, protein-rich health food."[10] The possibility of making large profits from shrimp cultivation led farmers and entrepreneurs to convert coastal lands into shrimp farms and to use intensive farming practices. With multinationals entering the industry, shrimp aquaculture quickly became a multi-billion dollar industry. Because of the way in which shrimp farming has rapidly changed the nature of the shrimp industry, aquaculture and shrimp culture specifically is referred to as the Blue Revolution.

MPEDA estimates that over 84,000 hectares of land from a possible 1.2 million hectares of suitable land have been converted to shrimp farms in India. Andhra Pradesh and Tamil Nadu are India's most intensive shrimp farming states. Between 1989 and 1993 the estimated area under shrimp culture in Andhra Pradesh grew from 3,430 hectares to approximately 11,000 hectares, and posted the fastest growth rate in India (Algaraswamy, 1995:37). This exceptional growth rate in many of India's coastal states, however, proved unsustainable after 1993.

1.4.2 Perfect Competition, Imperfect Knowledge

A shrimp virus outbreak in 1994 destroyed approximately 36 percent of the season's shrimp production in India (Lundin, 1996) and over 50 percent of the harvest in the south-eastern coastal states such as Andhra Pradesh (MPEDA,

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[10] Viswanathan (1994) quoting USA advertisements

1997). Those shrimp farmers lucky enough to receive news of the viral attack before their own ponds were infected, harvested early (with shrimp weighing only half their exportable weight) to cut their losses. However, even after the season's crop was mostly destroyed by the viral attack, shrimp farmers remained autonomous. Many farmers remained reluctant to share knowledge of their culture systems or disease prevention techniques with each other.

Three years on, few shrimp farmers attribute the viral attack to environmental stress and water pollution as a result of overfeeding and overall inefficient pond management. The majority of shrimp farmers claim the virus was carried by defective seed imported from Southeast Asia. According to this study many small scale and marginal farmers (owning under one hectare of water spread area) believe that the virus was spread to aquafarms through the air rather than via common waterways used by all aquafarmers for water intake and effluent discharge in a given locality. "How else would the virus have spread so quickly?", they argue. The gap in knowledge of the cause and spread of disease remains a hindrance to the sustainability of the industry.

Cultivating Technical Know-How

Since early on in shrimp farming's boom, big corporate bodies and medium scale entrepreneurs sought technical knowledge and appropriate pond management techniques from Taiwan, Thailand and Indonesia and sent employees on training missions to these countries.[11] At home, some small and marginal farmers rode on government subsidy schemes and technical knowledge disseminated by governmental institutes designed to promote the industry.[12] Essentially, fisheries extension officers were trained in brackishwater shrimp aquaculture through training courses offered by one of four government experimental research institutes in India. They, in turn brought knowledge of

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[11] Discussions with KAA farmers in February, 1997.

[12] The national promotional body is the Marine Products Export Development Authority and the Central Institute for Brackishwater Aquaculture. State funded bodies include the various regional Brackishwater Fish Farming Development Authorities.

shrimp culture techniques to the state, district and local *mandal*[13] level. However, in every state, less than one percent of all small scale and marginal aquafarmers benefited from government sponsored training programs (BFDA, 1997). The majority of small scale and marginal shrimp aquafarmers essentially claim to "learn by doing." In an environmentally sensitive agri-business such as shrimp culture, this is a dangerous proposition. The government, however, is not entirely to blame.

Government Intervention

Despite the widespread support of the industry by the government through subsidy schemes amounting to as much as one lakh Rupees per farmer[14], most small and marginal aquafarmers and corporate bodies were lured to shrimp culture by the possibility of large profit. In Nellore district, Andhra Pradesh the amount of land utilised for culturing shrimp grew at an alarming average annual rate of 45% from 1990-1997.[15] Overall, during the early periods of brackishwater shrimp aquaculture (mid-1980s to 1993) the government adopted a laissez-faire attitude, allowing shrimp farmers to explore the full extent of shrimp culture with little to no restrictions. This however, rapidly changed with the advent of the "white spot" viral outbreak in 1994 and a writ petition filed in the Supreme Court on behalf of coastal fishers which called for a ban of the sector.

In response to the 1994 viral attack, a six month "crop holiday" was declared by the government to allow proper cleaning of the ponds and flushing of the brackishwater waterways used for communal water intake and effluent discharge. Although some farmers obliged, a majority (60%) continued culturing only to face another viral attack after a few months (MPEDA, 1996). Still, however, there was very little co-operation between farmers.

A second major setback to the industry occurred in 1995 when heavy monsoon rains and a massive cyclone led to widespread flooding in India's south-eastern maritime states. Once again the industry lost a majority of its crop

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[13] local administrative area

[14] $2,857 in 1997 dollars.

[15] See Chapter 3

and impressed upon shrimp farmers the vulnerability of shrimp culture to the natural elements.

1.4.3 Bumper Harvests in 1996

In 1996, by contrast, shrimp farmers throughout Nellore district and indeed throughout India reported bumper harvests. The heavy monsoon rains of the previous year were believed to have essentially flushed and cleaned most brackishwater bodies along the coast. Most small scale and marginal shrimp farmers were able to produce two good crops in this year with output ranging from 400 to 700 kilograms per hectare using extensive culture techniques (Patil & KAA Database, 1997). An average output of two to three metric tons per hectare was enjoyed by big corporate and large individual farmers under modified and semi-intensive culture techniques. This translated into an estimated $US 435 million generated by cultured shrimp exports to major markets in Japan, the European Union and the United States. The thousands of shrimp farmers' hope of repeating their 1996 success in 1997 was dashed, however, with a ban on the sector by the Indian Supreme Court in December 1996. The SC decision was in part a result of the agitation of several NGOs claiming that shrimp farming was destroying the environment and the livelihoods of coastal inhabitants.

1.4.4 NGO Agitation Against Shrimp Farming

Environmental and social action groups agitating against shrimp farms in the coastal zone include the National Fisheries Action Committee Against Joint Ventures (NFACAJV), the Campaign Against Shrimp Industries (CASI), Land for the Tiller (LAFTI) a social action group of mainly landless labour, Gram Swaraj Movement (GSM), PREPARE, Peoples' Alliance Against Shrimp Industry (PAASI), Nellore Citizens Welfare Forum (NCWF), Resource Foundation for Science, Technology and Natural Resource Policy founded by Vandana Shiva, and *Sneha* founded by P. Christy. Several of these local NGOs are financially supported by more internationally known NGOs such as Christian Aid.

Mr. S. Jaganathan, the octogenarian Gandhian and Sarvodaya leader led mass contact programs, protests and public meetings throughout the Thanjavur-Cauvery basin, Nagapatnam and Quaid-e-Milleth districts in Tamil Nadu. With a slogan, "prawn farms are prison farms" he built a vibrant resistance movement supported by thousands of landless labourers, marginal agricultural farmers and fisher-folk.

Women from fishing communities organised themselves into Women's Societies in order to effectively agitate against the sector. Once working for the shrimp farms by either collecting shrimp fry or preparing bunds, several organised women groups have boycotted working for the shrimp sector. Environmentalists and NGOs joined hands with local villagers in agitating against the industry. Organised protests led to halts in pond construction work. Social tensions also resulted in heavy-handed police intervention and shootings in Tamil Nadu (Viswanathan, 1994:77; Rajagopal, 1995:3).

Government Brokered Deals

NGO and local agitation led to government brokered settlements between corporate shrimp farmers and local populations. For example, inhabitants of Kurru Pattapalam village led a mass protest against a nearby corporate farm which broke out in violence and led to the destruction of farm property. In the course of one year of the arrival of the adjacent corporate farm, the village's drinking water turned saline, their access to the sea was cut off, and their huts began to collapse (*The Hindu*, July 21, 1994). The district collector convinced the farm to pay a monthly fee to cover the cost of transporting potable water to the village. In another well known case government officials in Nellore District brokered a deal between five corporate shrimp farms, Rank Aqua, Aquamarine, Carewell, Bommidala farms and Sharani Sindhu Shrimp Farms and Kurru fishing village. The Rs. 4 million deal enabled the village to relocate itself to a more stable location (*The Hindu*, July 21, 1994).

Perhaps not surprisingly, agitation was directed against corporate farms and not against the multitude of small and marginal shrimp farmers culturing in the district. Small and marginal shrimp farmers seem to coexist with fisher-folk in coastal villages. In contrast, large and corporate farms have come under increasing pressure both locally and internationally.

1.4.5 1996 Supreme Court Ban

The first formal claim that the financial success of the shrimp industry came at the expense of the environment and local farming and fishing communities was made by S. Jaganathan, Chairman of the Gram Swaraj Movement (GSM) to the Supreme Court of India. The GSM is a voluntary organisation "working for the upliftment of the weaker section of society" (Supreme Court Notification, 1996:168). The GSM sought enforcement of the Coastal Regulation Zone (CRZ) issued by the Indian Government on February 19, 1991. The CRZ calls for the National Coastal Management Authority to safeguard coastal areas including marine life and coastal inhabitants. The GSM writ petition was filed by M.C. Metha a well regarded environmental lawyer in India and also Chairman of the Indian Council for Enviro-Legal Action.

The court first issued notice on December 12, 1994 declaring that first, "coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action (in the landward side) up to 500 meters from the high tide line (HTL) and the land between the HTL and low tide line (LTL) are (part of) the CRZ " and second, that all Indian States must not permit any industry to construct "up to 500 meters from the sea water at the maximum high tide." This order was subject to an inquiry on whether shrimp farming was indeed adversely affecting the coastal environment and its inhabitants. Nonetheless, the Supreme Court in 1995 called for immediate protection of coastal inhabitants whose lives were allegedly suffering because of brackishwater shrimp aquaculture development. The court mandated that (1) beach access be given to fishers through private shrimp farms; (2) conversion of agricultural lands to shrimp farms be banned; (3) groundwater abstraction for shrimp farming be immediately stopped; and (4) each developing shrimp farm must obtain a pollution certificate. This was the first real attempt by the government to regulate the industry. However, enforcement was a problem and many shrimp farmers managed to avoid abiding by the new laws.

The NEERI Report

On March 27, 1995, the court passed an order calling for the National Environmental Engineering Research Institute (NEERI) based in Nagpur, India to impartially investigate the impacts of shrimp farming and report back to the court. Based on the NEERI Report's conclusions, on December 11, 1996 the GSM were rewarded by a ruling that called for the "destruction/closure" of all shrimp farms operating within 500 meters of any brackishwater body by April 1, 1997 (Supreme Court Notification, 1996:62).

In response to the court's decision, newly formed aquaculture associations successfully lobbied state and national parliamentarians. They argued that the NEERI Report was "unscientific" and that the court's decision was based on circumstantial evidence. In fact some internationally based NGOs have suggested that the NEERI Report has become the most controversial assessment of ecological and social costs of shrimp aquaculture (Mathews, 1997:1). This is a result of the ongoing debate between local NGOs and the international scientific community regarding the validity of the report's overall methodology and conclusions. For example, over twenty international experts publicly condemned the report as "amateurish...and unscientific...,"[16] "partisan and misleading...biased,"[17] and "unprofessional...and based on faulty data."[18] The cost-benefit analysis in the report includes only the social and environmental costs of shrimp farming without any mention or inclusion of benefits accrued from employment and growth of ancillary industries.[19] NGOs, on the other hand

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[16] T.V.R. Pillay, Former Head, Aquaculture Division, FAO

[17] E.G. Silas, Former Director, CMFRI

[18] Rathin Roy, Senior Advisor, UNBOBP, FAO

[19] Today, it is both nationally and internationally accepted within the scientific community that the NEERI Report does not appropriately assess the environmental and social impacts of shrimp

naturally support the report's findings, however, with slight reservations. They offer very little comment on the method in which NEERI conducted their investigation.

On March 18, 1997 the Indian Parliament passed the 1997 Aquaculture Act which placed a moratorium on the original Supreme Court order, effectively saving the industry. Since then, however, the shrimp farming sector has been in a state of flux. Because of the two-time collapse of the Indian Government in 1997, the Indian Parliament has been unable to take further action on shrimp aquaculture. In the meantime, the aquaculture industry and NGOs continue the debate whether shrimp can be cultured in an environmentally and socially sustainable way. This debate has now gained international importance. Despite a lack of clear direction, the Supreme Court order and subsequent events have put shrimp farmers on the defensive. Domestic and international pressure to prove that shrimp can be farmed sustainably has been placed squarely with the many aquaculture associations formed to protect the rights of their members. As early as a few weeks after the landmark judgement, shrimp farmers began to organise throughout India. This private and collective action, may in fact be the saving grace of the industry.

1.4.6 Opportunities for Collective Bargaining[20]

Since the Supreme Court's decision to put an end to the export-led Indian shrimp farming sector, a number of important changes have taken place at the local level that may help ensure a degree of environmental sustainability. Previous to the ban, shrimp farmers shared little technical information with each other. Any knowledge transfers that occurred, took place within small extended family owned farms. Farmers were too busy in their daily culture operation to discuss production techniques like efficient feed use, appropriate stocking

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farming in India. NGOs, however, continue to use the facts and figures presented in the report in their own crusade against the industry.

[20] This sub-section is based on a compilation of my notes from group discussion with several dozen small, medium and large scale farmers culturing shrimp along the Kandaleru river.

densities and effluent treatment with neighbouring farmers.[21] As far as most were concerned, shrimp culture put previously unproductive "wasteland" to productive use and generated income far greater than any small scale crops traditionally grown on soils with moderate salinity. Each farmer operated in a perfectly competitive market with plenty of room in the market (and along brackishwater bodies) for entry of additional farmers and more competition. However, unknown to most shrimp farmers was the sensitivity of their lucrative crop to environmental stress, unpredictable seasonal changes (i.e. periods of heavy monsoon and cyclones) and to each other's production methods.

Moreover, since the December 1996 Supreme Court order banning the industry, large public and private corporate farmers and the multitude of small scale farmers have rapidly banded together to save the sector and their own livelihoods. Between mid-December 1996 and March 1997, dozens of Shrimp Aquaculture Associations (SAAs) have arisen throughout India's coastal districts. Each SAA comprises of both big and small shrimp farmers, rich and poor alike, farming around a specific brackishwater body. District-wide and state-wide associations have also recently formed where representatives are selected from among the executive committee members of local associations. By April 1997 the All India Aquaculture Association had formed.

The Kandaleru Aquafarmers' Association (KAA) is a local organisation comprising of over 500 shrimp farmers that formed after the Supreme Court judgement. The farmers cultivate shrimp along the Kandaleru river, Nellore district, Andhra Pradesh (see the map presented in Figure 2.0 in Chapter 2). Each group of ten aquafarmers from a specific village locality select one member representative to the Association's board. The board selects an Executive Committee made up of an Honorary President, President, vice-president, Secretary, Joint Secretary and Treasurer to take forward local level concerns to the necessary State and National bodies. In addition to the Executive Committee, an Action Committee comprising of press, technical, administrative, revenue and legal sections implement the decisions made by the Board. Decisions taken by

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[21] This is based on semi-structured group interviews of Kandaleru shrimp farmers held in February, 1997.

the Board are made known to the local farmers through their elected member. In the case of the KAA, there appears a high degree of solidarity.

For example, when the Supreme court order outlawed aquafarms operating within 500 meters of any brackishwater source, the Board decided that all farms along the Kandaleru would protest the court's decision as a unified body. Even the few dozen aquafarmers unaffected by the apex order (i.e. those operating beyond the 500 meter mark) did not culture and therefore lost profits from a potentially lucrative crop. This level of solidarity and collective action may help promote the long run sustainable growth of the industry.

1.4.7 Benefits of Collective Action

The Supreme Court order has essentially managed to collectivise an otherwise disorganised, individualistic and solely profit-minded industry. The motivating factor in the development of regional associations has certainly been to fight the court order. However, in the long run, these associations could play a vital role in sustainable development efforts if amendments to the CRZ regulations are made such that shrimp aquaculture is exempted, albeit with a degree of modification.

First, corporate and small scale aquafarmers alike are just beginning to realise that their future growth and development depends on a clean environment. Co-operation could ensure that each farmer has access to greater scientific knowledge of their own production. This research suggests that there exists an overall lack of awareness of the necessity of a clean water source for shrimp culture among Kandalery shrimp farmers. As most shrimp farms in a specific locality use the same brackishwater source to fill their ponds and discharge their effluent, the probability of contaminating their downstream neighbour's intake water is high. In fact, the viral disease outbreak of 1994 was most likely spread through common waterways. This general ignorance, however is changing with the formation of SAAs.

Second, smaller shrimp farmers will benefit from greater co-operation. With opportunities for small and marginal shrimp farmers to bargain collectively, they will be able to reduce their overall input costs by purchasing vital inputs such as hatchery seed at bulk discounted rates. Currently, corporate farms buy in excess of two million seed in bulk from hatcheries at a rate of Rs. 0.35 a piece. Small and marginal farmers pay a higher rate (up to Rs. 0.60 a piece) for a smaller volume (35,000 to 60,000 pieces). With collective action, groups of small shrimp farmers could purchase larger quantities at lower prices and distribute them amongst themselves. The same applies to other inputs such as feed and with capital costs such as motorised water pumps which could be shared between several marginal farmers. More importantly, however, are the benefits extended to the environment. With the ability to purchase hatchery seed at affordable prices, the stress placed on marine ecology from purchase of wild caught seed collected by coastal fishers will decline. This will also benefit coastal fishers. Shrimp fry previously caught and sold for pond stocking shrimp fry would now be able to grow to maturity in deeper off-shore waters. Local fishers would benefit from catching larger shrimp which have a higher per unit value realisation than shrimp fry.

Third, reduction of supplementary feed could ensure that the likelihood of breaching the carrying capacity of the pond is minimised. This would in turn minimise the production costs per kilogram of shrimp enabling small and marginal shrimp farmers to enjoy higher levels of profitability even when operating below their potential maximum yield. At a lower use of feed input, the possibility of pond bottom deterioration and water quality improvement may be achieved. Shrimp farmers would thus be operating at the maximum sustainable yield. This means that although output levels may decline from 1996 levels, the longevity of the production system would be extended with minimal output fluctuations from disease outbreaks (due to higher overall water quality) and thus less stress placed on the environment. Co-ordination between farmers would ensure that the latest scientific discoveries of appropriate feed use be shared quickly in a given region.

Fourth, private individual and corporate farmers would also benefit from greater co-ordination. Through the SAA, all shrimp farms along a brackishwater body could be monitored for viral attacks. Once a virus was detected, news could spread quickly to other farmers who would have appropriate action plans to save their crop. As large private and public corporate farms come to understand their dependency on even small and marginal farmers and other larger farmers for clean water intake, they will further support each other in disseminating knowledge of how to protect their common property resource, the brackishwater body.

Fifth, greater co-ordination between farmers means more opportunity for appropriate government regulation of the industry. For example, governmental use of existing informatic resources could ensure that the industry is appropriately regulated and develops sustainably to ensure that environmental degradation and disturbance to rural populations is minimised. Data obtained by space-borne remote sensing satellites coupled with geographic information system (GIS) can be used to identify environmentally fragile zones surrounding precious groundwater sources, fertile agricultural lands, and local village communities. Using these data, decisions could be made on which areas are suitable and unsuitable for shrimp aquaculture development. This data could be shared with each regional SAA to map areas of possible conflict between the industry, the environment and local populations. Satellite data could thus supplement ground level analysis and play a powerful role in monitoring and protecting India's vast coastal resources and its traditional inhabitants.

The hope is that all members of Shrimp Aquafarm Associations will begin to share technical knowledge of culture practices, information on disease prevention through eco- friendly pond and effluent cleaning systems and scientific knowledge regarding the state of the environmental carrying capacity throughout the culture period. Although members of the SAAs appear willing to collaborate towards educating each other regarding sustainable aquafarming practices, it remains to be seen if this is solely lip service for the purpose of lifting the ban on shrimp culture. All members seem to agree, however, that there is plenty of room in the market for healthy growth of the industry. However, it remains to be seen that the various aquafarmers' associations will continue collaboration if allowed to continue culture practices. As the market becomes saturated, and profit margins fall due to sharp declines in prices perhaps each aquafarmer will find it in his own interest to keep innovations to himself, thus undermining the strides made from collective action. This could be avoided through appropriate regulation and/or diversification of value added shrimp products. However, so far, it seems that the Supreme Court order could be seen as a blessing in disguise for the shrimp culture industry.

1.5 Research Objectives

The lack of research on the social, economic and environmental impacts of brackishwater shrimp farming in India has become of major national importance as a result of the Indian Supreme Court's December 1996 decision to ban the industry and destroy any farms located less than 500 meters from any brackishwater source.[22] In an emergency session in March 1997, the Indian Parliament passed the *1997 Aquaculture Act* that placed a moratorium on implementing the court order. This Act called for the establishment of an Aquaculture Commission to establish regulatory guidelines for the sustainable development of the shrimp farming sector.

To ensure that the Commission devises an appropriate regulatory framework to promote sustainable shrimp farming, several questions regarding the social, environmental and economic impacts of this sector must be answered. This amounts to exploring answers to key questions raised within three under researched areas of concern: (1) examining the relationship between shrimp farming and the impact of changing land use patterns on agricultural labour; (2) evaluating the productive performance of the shrimp farms themselves with respect to efficiency and sustainability; and, (3) measuring the socio-economic and environmental impacts of shrimp farming on local inhabitants. These are difficult tasks since the necessary data needed to explore these areas of research are deficient. Additionally, very little is known about this sector because it has developed and gained local and international attention only within the past five years.

The core objective of this research is therefore, to model and measure the efficiency of the brackishwater shrimp aquaculture sector and its socio-economic and environmental impacts on rural producers in India. This is accomplished within the context of a microeconomic analysis of the shrimp farming sector's growth and development in the Kandaleru region, in particular. The Kandaleru region is located in Nellore district, Andhra Pradesh and is not dissimilar to the dozens of shrimp farming regions located throughout India.

1.6 Contributions of this Research

The specific study of shrimp production in the Kandaleru region and its socio-economic and environmental impacts on coastal producers make several significant contributions to the empirical field of study. Each contribution is based primarily on the analysis of one of three primary data sets collected from six months of fieldwork in India: (i) a general survey of over 500 shrimp farms; (ii) a detailed data set of production characteristics collected by surveying 82 shrimp farms; and (iii) a survey of coastal producers inhabiting one of twenty-six villages located adjacent to major shrimp farming areas. Moreover, the results themselves provide policy relevant recommendations which may contribute to the existing debate on the sustainability of shrimp farming. Specifically, the core contributions arising from this dissertation are a result of the following six areas of research.

1.6.1 The Growth & Development of the Shrimp Farm Industry

Current research on the growth and development of India's shrimp farming industry is vague and anecdotal. This is mostly a result of limited survey data collected on general characteristics of shrimp farms and on ancillary services. This dissertation fills this void by analysing relevent primary data. The data analysis identifies relationships between farm size, ownership status, production technology, factor inputs and shrimp output of Kandaleru shrimp farms and traces its growth and development between 1993 and 1997. Similarly, the evolution, growth and development of ancillary services are examined. Analysis of both together, serves as a comprehensive review of one of the most

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[22] *S. Jaganathan vs. G.O.I. (Kuldip Singh, J), December 11, 1996.*

prolific shrimp farming regions in the most prolific Indian shrimp farming state, Andhra Pradesh.

1.6.2 Direct & Indirect Employment

There have been few studies and much speculation regarding direct and indirect rural employment opportunities generated from brackishwater shrimp farming. Direct employment arises from either owning and operating a shrimp farm or by working for one. Indirect employment opportunities arise from the growth of ancillary services such as seed hatcheries, feed mills, ice factories and processing plants. Employment levels generated directly and indirectly from the growth and development of the shrimp farming sector and its accompanying ancillary services are assessed.

1.6.3 The Changing Pattern of Land & Labour Use

There is much debate as to how the growth of shrimp farming in the Kandaleru region has affected the pattern of land use and consequently the structure of the rural labour market. Government land previously classified as barren and unproductive is now supporting shrimp culture. Simultaneously, agricultural land is allegedly indiscriminately converted to shrimp farms as traditional agricultural farmers realise the potential for greater profits by farming shrimp. Moreover, there is growing concern by local and international NGOs over more frequently reported incidents of ground water salinity, agricultural land salinity and other environmental externalities. These are believed to be caused by shrimp farm development. In addition, the impact of both agricultural and non-agricultural land conversion on the local labour market is of concern. Overall, there are many questions, but few answers with respect to shrimp farming and the impact of changing land use patterns on agricultural labour. Therefore, this research explores the hypothesis that traditional agriculture and agricultural labour have been displaced since the advent of shrimp farming.

1.6.4 Modelling & Measuring Shrimp Farm Efficiency

Very little is known about the economic performance of the shrimp aquaculture sector except that it is extremely volatile with significant profit made during a good culture cycle and financial losses and even bankruptcy as a result of crop failure from disease. This volatility translates to economic instability in the rural economy which has direct and indirect consequences for the shrimp farms themselves, ancillary services, and for the rural labour market. There are additional impacts as a result of price fluctuations in the international marketplace that can affect the overall rural economy since shrimp production is primarily an export-led sector. There has been a lack of adequate research on these topics as a result of insufficient microeconomic data. This is due to a combination of factors that include investing the necessary time and resources to carry out a rural based survey in a disorganised sector and the unwillingness of producers to share sensitive production data. In addition, shrimp farming has been met with local opposition which has made shrimp farmers protective of their trade and data collection efforts even more difficult.[23]

Because of growing social activism against shrimp production in rural areas of India, shrimp farmers have become wary of outside interest in their culture activities. This has made it exceedingly difficult for researchers to gain access to production statistics as well as descriptive data on the size of farms and the managerial characteristics involved in operating that farm. Therefore, very few comprehensive production data sets exist for shrimp farming. The data that do exist, however, are collected from government managed experimental stations and not from private shrimp farmers themselves. Only a few studies have analysed solid production data collected from the field. These studies, however, follow a handful of farms through several culture cycles and are therefore unrepresentative of a specific region. The advantages accrued as a result of analysing shrimp farm production is two-fold: to model, measure and explain technical and scale

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[23] Several medium and large scale shrimp farmers have put barbed wire around their farms to protect their crops from possible sabotage from local opposition groups.

inefficiencies among sample shrimp farms; and, to answer important questions regarding the economic behaviour of shrimp farms.

1.6.5 Identifying Environmental & Socio-economic impacts

No rigorous economic analysis exists on the impacts of shrimp farming on indigenous populations.[24] A number of qualitative accounts based on informal interviews of villagers have been circulating. Qualitative studies provide good descriptive accounts of the ways in which rural populations have benefited and/or suffered as a result of shrimp farming. A majority of these published reports, however provide nothing more than anecdotal evidence at best to substantiate their claims.[25] This is often a result of unstructured, unsystematic and overall haphazard data gathering efforts.[26]

The value-added of a comprehensive survey of rural populations inhabiting villages adjacent to shrimp farms is therefore three-fold: (i) to consistently and rigorously identify the negative social impacts of shrimp aquaculture development (i.e. caused by both environmental and non-environmental impacts of shrimp farming) on rural populations; (ii) to rank these concerns; (iii) to measure the severity of socio-economic problems the region faces as a result of shrimp farming.

1.6.6 Assessing the Determinants of Social Impacts

The final contribution of this research is an attempt to assess the determinants of social impacts on twenty-six villages surveyed in the Kandaleru region. Specifically, three questions are explored employing Probit and Ordered Probit models: (i) What are the determinants of social impacts faced by coastal and inland communities as a result of shrimp farming?; (ii) What farm and

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[24] This conclusion is reached through a comprehensive review of the literature presented throughout this research. Moreover, the same conclusion is substantiated by comprehensive reviews of literature on shrimp farming and its impacts conducted by the World Wildlife Fund (see Clay, 1997), the United Nations Research Institute for Social Development (see Barraclough & Finger-Stich, 1997) and the World Bank (see Hempel & Winther, 1997).

[25] Some examples include Bundell & Maybin (1996), Justice et al. (1996), PREPARE (1996).

[26] The most well known example in the Indian context is the NEERI (1996) report discussed earlier in this chapter.

village characteristics, if any, explain why some villages are more or less likely to suffer from the negative consequences of a given social impact?; (iii) What impact does a small change in a significant village or farm characteristic have on the probability that the region suffers from a particular socio-economic or environmental problem? This empirical investigation is the first of its kind in assessing shrimp farming's impacts on coastal inhabitants.

Chapter 2
Survey Methodology & Data Collection

2.0 Introduction

Six months of fieldwork in the Kandaleru region of coastal Andhra Pradesh, India took place between November 1996 and April 1997. Sample survey methods were used as the primary survey instrument due to its economy, adaptability and overall accuracy (Casley and Lury, 1981:48). The basic survey instrument and technique were adjusted to fit the local socio-economic and demographic conditions. Overall, the techniques used to collect micro level data required refining over several months before arrival in India and rapid alterations to the basic survey structure when in the field.

This chapter presents a detailed account of the methodology devised to collect (i) basic information on over 500 shrimp farms operating along the Kandaleru river needed to survey basic characteristics of the sector in this region; (ii) detailed production data needed to model and measure shrimp farm efficiency; and, (iii) community data used to assess the environmental and socio-economic impacts of shrimp farming on coastal inhabitants in south-eastern India. A detailed description of the fieldwork location is presented is section 2.1. An account of the historical and current events that helped facilitate the data collection effort is discussed in section 2.2. Section 2.3 discusses the methodology to construct and implement the 518 shrimp farm survey. Section 2.4 discusses the methods employed to survey inhabitants of twenty-six villages located adjacent to Kandaleru shrimp farms. Section 2.5 presents the methodology used to obtain detailed production data for a sample of 82 Kandaleru shrimp farms. Finally, some concluding remarks are offered in Section 2.6.

2.1 Description of Fieldwork Location

Nellore district is the southern most coastal district in Andhra Pradesh, a southeastern Indian state (see Figure 2.0). The southern most coastal state in India, Tamil Nadu is located directly to the south of Andhra Pradesh. Karnataka and Maharashtra are to its West, and Madhya Pradesh and Orissa are Andhra Pradesh's northern neighbors. Nellore district is bounded by a 163 kilometer eastern coastline along the Bay of Bengal. It is sub-divided into twenty *mandals*, or administrative regions of which fourteen support brackishwater shrimp aquaculture (BFDA, 1996). Five major brackish rivers, namely, *Pennar*, *Swarnamukhi*, *Pyderu*, *Chippaleru*, *Kalangi* and *Kandaleru* flow through this district and into the Bay of Bengal. The Buckingham Canal, a British made canal used to transport goods through the state runs parallel to the coastline and traverses the district. As a result of good brackishwater sources, the region has witnessed the rapid development of the shrimp aquaculture sector.

The Kandaleru river[1] and surrounding region was chosen as the study site for this research for primarily four reasons. First, the Kandaleru river is unique in that it does not play host to any large scale industry other than to shrimp farming. Shrimp farms occupy both northern and southern banks of the river's fifty kilometer stretch upstream from the Bay of Bengal. The only competing large scale agricultural commodity produced in the region is paddy. Crops such as bananas, ragi, salt and casuarian are cultivated at a much smaller scale. Although it is not uncommon that agricultural run-off containing pesticides and herbicides can pollute adjacent rivers, paddy cultivation does not have a history of polluting the Kandaleru (Rao, 1995:2). The Kandaleru river is therefore a model brackishwater body from which insights can be made regarding the impacts of brackishwater shrimp aquaculture on the environment and on local populations inhabiting its banks (CIBA, 1997; Rao, 1995:3).

Second, a variety of good quality secondary data exist for this region because of the river's close proximity to the district capital, Nellore. Nellore city

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[1] Throughout this research the Kandaleru river is also referred to as the Kandaleru creek or Kandaleru basin.

is the district's administrative center and hosts all the major government offices that oversee shrimp farming. These include the Brackishwater Fish Farmers' Development Authority (BFDA), Inland Fisheries Inspection Office (IFIO), Pollution Control Board (PCB), Central Planning Office (CPO), Land Records Office (LRO), and District Collector's Office (DCO). Each one of these offices was visited. Moreover, publicly available secondary data were collected from them. Approval to conduct field research in Nellore district was granted by the BFDA since the Kandleru region fell under its authority. Moreover, Nellore city also hosts many of the ancillary services that support shrimp farming activities. These include ice factories, seed hatcheries, feed mills and peeling and processing plants. Several were visited and managers were interviewed informally.

Third, because of the Kandaleru region's local fishing port at Krishnapattanam and close proximity to a major rail link to Madras[2] (Gudur & Nellore), shrimp are easily transported for export. Therefore, shrimp farming in the region has boomed in a relatively short period of time.

Finally, much of the literature and activism denouncing the shrimp aquaculture industry focuses on villages and farms located in Andhra Pradesh and Nellore district in particular. Moreover, several documents considered by the Indian Supreme Court cite the district by name and several of the official and unofficial reports used against the shrimp industry are based on studies conducted in the Kandaleru region.[3]

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[2] The offical name of Madras was recently changed to *Chennai.*

[3] These studies are produced by a range of Non-Governmental Organizations (NGOs) and government offices. They range from collections of field notes based on personal observation to analysis of survey data. Brief reviews of these studies are presented in Chapter One.

Figure 2.0

Map of India, Andhra Pradesh & Nellore District

2.2 Background to Fieldwork

The empirical field investigation of shrimp farms and the assessment of shrimp farms' impact on rural communities took place between early November 1996 and April 1997. The first month proved difficult as a result of the rapidly changing political climate. Initially, I intended to first survey Kandaleru shrimp farms to obtain data on general farm characteristics and more detailed production data. Farmers, however, were uncooperative in early November, as it was the harvest period and the busiest time of the year. Due to their unwillingness to cooperate, I decided to concentrate on conducting village impact surveys. After conducting a pilot survey in one of the Kandaleru villages, the political climate changed again, enabling me to turn back to surveying shrimp farms. This time, however, I had a substantial degree of support from farmers. The Supreme Court had essentially banned the sector in mid-December, 1996. The chronology of events summarized above is now discussed in greater detail.

Initial attempts to gain access to primary information regarding shrimp farm production failed. Several corporate shrimp farm administrative offices located in Nellore city were visited over two weeks. Most of the managers in charge of record keeping refused outright to discuss details of their farm production characteristics. November 1996 was the shrimp harvest period.[4] Most shrimp farmers were actively engaged in harvesting their shrimp crop and often too busy to answer survey questions regarding their culture methods. In fact, most of the corporate farm managers and larger scale shrimp farmers were suspicious of the interest shown in their production methods. This was a consequence of the national and international attention that both local and foreign environmental and social activists had raised in their attempt to ban the industry.[5]

Larger shrimp farmers were very aware that several international NGOs with local representation through sister organisations in India were claiming that

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[4] Although I realised before arriving in India that this could pose a problem, I was obliged to begin my field research at this time due to stipulations set by my funding source.

[5] There were several NGOs actively campaigning against the shrimp farming sector in Andhra Pradesh and Tamil Nadu, India at that time. More well known NGOs include the Gram Swaraj Movement under the leadership of S, Jaganathan, the Campaign Against the Shrimp Industry

the brackishwater shrimp aquaculture sector was disturbing the balance of the coastal ecosystem through blatant disregard to the environment. Secondly, activists argued that the sector was displacing local inhabitants from their traditional occupations and in some cases displacing local peoples from their ancestral homes. In addition, activist groups had organized non-violent demonstrations against the sector. These demonstrations were held frequently at the local, state and national level. Shrimp farmers were additionally concerned about a 1994 petition calling for an outright ban on the shrimp farm industry. In November 1996 this matter was under consideration before the Indian Supreme Court.

During the first month of fieldwork in the shrimp-farming belt of southeastern India, it became clear that a different approach was needed. The period between crop cycles (December to February) seemed more likely to yield better results.[6] The focus, therefore, shifted away from eliciting farm level data and more toward conducting village impact surveys. The rest of November was spent piloting the village impact survey prepared in collaboration with the Central Institute for Brackishwater Aquaculture to assess the impact of shrimp farming on local inhabitants living adjacent to the Kandaleru shrimp farms.[7]

As the 1996-1997 Rajiv Gandhi Foundation (RGF) Scholar, I was well received by many of Nellore city's government offices. A letter of introduction from RGF proved very useful. The Chief Executive Officer of Nellore's BFDA officially sanctioned two Fisheries Development Officers to assist me during the duration of my investigation.[8] Each of the two Fisheries Development Officers had at least eight years of experience in the BFDA and four years of experience in the Kandaleru region. Their primary responsibility over the four years was to

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(CASI), Land for the Tillers Freedom (LAFTI), The Association of the Rural Poor (ARP), PREPARE and the Churches Auxiliary for Social Action (CASA).

[6] I believed that as a result of their successful harvests and the interim idle phase, shrimp farmers might be willing to speak more freely and at longer intervals.

[7] The Central Institute for Brackishwater Aquaculture (CIBA) is the government agency in charge of promoting sustainable shrimp and fish aquaculture in India. CIBA, with its headquarters in Madras (Chennai) has several experimental stations around the country staffed with fisheries biologists and other fishery experts, scientists and fisheries economists. The pilot survey questionnaire was prepared at the London School of Economics and based on issues raised by secondary sources. The pilot study was modified after discussions with shrimp farm experts at CIBA to include local level concerns.

[8] BFDA Chief Executive Order (November, 1997).

oversee shrimp farming in the region. A part of their responsibilities was also to monitor the concerns of village communities located in the shrimp-farming belt of the Kandaleru region. Both officers were fluent in the regional dialect and in English. Moreover, one officer had specialized knowledge over the sea-based villages located adjacent to sea-based shrimp farms, while the other officer was responsible for villages located adjacent to the Kandaleru creek. Both officers proved invaluable in helping to administer village surveys that were prepared to address the impacts of shrimp farming on local inhabitants' well-being.

In early December, a pilot survey of one of the Kandaleru creek-based villages was conducted. However, the landmark decision by the Indian Supreme Court soon after, forced me to shift my focus from the villages back to the shrimp farms. This proved to be the turning point in my data collection activities. Detailed accounts of the survey methods are discussed next.

2.3 Shrimp Farm Survey Methodology

2.3.1 Preparing & Administering the Survey

In mid-December 1996 the Indian Supreme Court effectively imposed a national ban on all shrimp aquaculture production units. The order was effective immediately. As that season's bumper harvest generated significant profits for all those involved in both production and in the supporting ancillary services, and enabled many farms to enjoy a healthy profit after several crop failures, this judgment was devastating.

Acting as an unofficial advisor to a group of local corporate shrimp farmers operating along the Kandaleru river, I participated in guiding the launch of the first Kandaleru Aqua Farmers' Association (KAA).[9] In doing so, I

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[9] At this stage, corporate shrimp farmers no longer viewed me as a threat, but as a possible ally in their attempt to organize. This was a result of my connections to the Rajiv Gandhi Foundation which I believed they confused with the Rajiv Gandhi Foundation for Aquaculture located in Tamil Nadu. I also managed to gain the confidence of the local Rotary Club President who also

stepped out of what could be seen as objective neutrality (Wolcott, 1995: 165-166). However, Kincheloe and McLaren, (1994:140) suggest "whereas traditional researchers cling to the guard rail of neutrality, critical researchers frequently announce their partisanship in the struggle for a better world."[10] My informal participation in the KAA does raise the question of data reliability. However, as discussed below, the method of data collection employed puts possible data bias into context.

The idea of the KAA was to collectivize the farmers culturing shrimp along the Kandaleru and form an Association with an elected board that could lobby against the Supreme Court's decision. The first step was to announce the establishment of the KAA and solicit members. Over a period of a few weeks I accompanied a small group of corporate sector managers and large scale farmers and visited several shrimp farming localities along the Kandaleru. The group explained the meaning of the Supreme Court judgment and the reasons for initiating the KAA. Farmers were asked to form into groups of ten to fifteen and elect a representative from that group who could attend KAA meetings and communicate information back to the group.[11] Approximately 42 representatives were elected to represent approximately 530 shrimp farmers.

Through each elected representative, my questionnaire, which also served as their official KAA "Membership Enrollment/Information Form" (EIF) was sent to all known shrimp farmers via the group leader (see section 2.3.3)[12]. Each farmer was expected to return the questionnaire with a joining fee of Rs. 100 to gain membership to the Association.[13] A registration number between 1 and 530

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had several dozen hectares of shrimp ponds and therefore some clout amongst the shrimp farming community.

[10] Although I don't claim to be aligning myself with the shrimp farmers to somehow better the world, I did see an opportunity to gain substantive knowledge and data through my alliance.

[11] Only two farmers were selected to represent over 150 marginal scheduled castes and scheduler tribes (SC-ST) farmers operating on land transferred to them by the government for the purpose of shrimp farming.

[12] This method introduces the risk of selection bias. However, the response rate of over 98 percent suggests that the group leader did take responsibility to ensure each of his constituents filled out the questionnaire.

[13] Marginal farmers who operated on land less than one hectare were exempt from the joining fee. Owner-operators on farms of a size greater than one hectare were thought to be able to pay the nominal joining fee. Our discussions with small farmers suggest that the joining fee was not a deterrent from joining the KAA. Farmers with multiple farms were asked to register each farm. It is possible that the estimation of 530 Kandaleru shrimp farms is an underestimate,

identifying each shrimp farm was placed on each EIF.[14] This number served a dual purpose: first, as a registration number and second, as a way of systematically counting the number of farms and keeping track of which farmers under each elected KAA official's jurisdiction did not respond. Later I benefited from the fact that the KAA registration number also enabled me to follow up on the survey responses of individual farmers in a systematic way. This was most useful in my effort to collect production data from 82 sample KAA farms located adjacent to Tikkavaram and Bestapalem villages.

By mid-February 1997 the KAA had received almost 90 percent of the EIFs and by the middle of March, 98 percent had been received. Cross sectional data on basic farm characteristics are therefore collected for 518 shrimp farmers culturing along the Kandaleru creek, Nellore district, Andhra Pradesh.

2.3.2 Quick response

The motivation for owner-operators of marginal, small and medium size farms and managers of corporate sector shrimp farms to join the KAA and quickly return the questionnaire was two-fold. First, shrimp farmers along the Kandaleru were forced to stop producing shrimp due to the mid-December 1996 Indian Supreme Court judgment. However, the court also ruled that all shrimp farms operating within 500 meters of the high tide line would be demolished by the end of March 1997. Approximately 98 percent of all shrimp farms in this region fall within this exclusion zone called the Coastal Regulation Zone, or CRZ (BFDA, 1997). Second, both small and large size shrimp farmers had little hope to save their livelihood without some form of collective action. They saw the initiation of the KAA as one positive step towards collective bargaining with the government.[15]

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however. Any conclusions drawn from this research naturally corresponds to KAA shrimp farmers. It can be generalized to brackishwater shrimp farmers in general as a result of the relatively uniform modes of culture within India's coastal shrimp farming states.

[14] According to the KAA Board of Directors, there are no more than 530 shrimp farms located along the Kandaleru. This, however, may be a slight underestimate of the true number of farmers.

2.3.3 EIF Questionnaire

The final list of questions appearing on the EIF questionnaire was determined through semi-structured discussions with a subgroup of shrimp farmers in mid-December 1996.[16] From these discussions, I discovered that shrimp farmers were not prepared to formally share certain production data and specific characteristics of farming methods via a formal questionnaire.[17] These data were considered sensitive and private. With all farms identified by a specific KAA registration number, managers and owner-operators of each one could be followed up by the survey team for more specific and sensitive data collection. Overall, the general KAA survey response rate was an outstanding 98 percent. Thus with little possibility of selectivity bias, the conclusions drawn from the data can be said to accurately reflect the characteristics of the shrimp farming sector in the Kandaleru region.

For the purpose of the EIF questionnaire, shrimp farmers occupying land on either the northern or southern bank of the Kandaleru were invited to join the KAA and to be included in the survey. Sea-based farms near but not adjacent to the Kandaleru were excluded from the KAA and therefore also from the survey.[18] However, 1996 and 1994 sea-based shrimp farm data were collected from the office of the regional Brackishwater Fish Farming Development Authority (BFDA) located in Nellore city. Similarly, general survey data on 1994 Kandaleru shrimp farm characteristics were obtained from the same government agency. These data allow for some comparison between two time periods, the 1993-1994 and 1996-1997 seasons.

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[15] This issue was discussed in Chapter One.

[16] The original survey was prepared by myself at the London School of Economics. This was altered in the field to take into account local conditions. Several informal group discussions between myself and shrimp farmers took place at the guest house where I was based. The guest house was located in Gudur, the unofficial administrative center for the Kandaleru river. As a result of its close proximity to one cluster of shrimp farms (less than three kilometers), several small and marginal farmers also participated in the group discussions.

[17] Farmers were unwilling to disclose certain information regarding production technology as a result of Indian Supreme Court Interim Order W.P.No.561/94 dated 9-5-95 which asked the State Government to place restrictions on shrimp farm units using specific culture technology. The EIF questionnaire, therefore asks for only basic (i.e. unthreatening) information on each farm.

[18] Sea-based farms are those shrimp farms adjacent to the Bay of Bengal. These farms use the Bay of Bengal for both water intake and effluent discharge.

The EIF, written in English and in the local language asks each responding shrimp farmer to answer several questions characterizing their farms.[19] The EIF asks each farmer for the name and address of the owner-operator and the location of the farm (i.e. nearest village). It asks for exact figures for each farms' total land holding, total water spread area, total number of shrimp ponds, average yield per hectare during the bumper harvest of 1996 and during the disease year harvest of 1994 (or average yield per pond if the per hectare figure was unknown), land ownership status (leased, owned or government transfer), and location (i.e. name of the nearest village and approximate distance in kilometers from the farm). Illiterate shrimp farmers were assisted with the EIF by one of the elected KAA representatives.[20]

2.3.4 Bias

There are two types of bias that may be some cause for concern. The first type concerns the survey structure, sampling method adopted, and overall sample size. The second type arises from non-response and fictitious or exaggerated responses. Both forms of bias can easily lead to inappropriate conclusions as a result of bad data. While bias undoubtedly exist to some degree in the data, the question remains as to whether it is of significance.

The EIF survey asks for only general information on characteristics of farms operating along the Kandaleru river. As a result, there were no non-responses to questions. In several hundred cases, farm sizes and the area water spread were given in acres. These figures were simply converted to hectares.[21] When the area unit was left off the size figure, it was not difficult to figure out

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[19] An example of the EIF is presented in Appendix 2A.

[20] Each group of approximately ten shrimp farmers in each shrimp farming region along the Kandaleru elected one representative to the KAA Board. This representative in all cases was literate and served as the liaison between local farmers and the KAA. In each case, the representative elected was male, despite the fact that some farms are registered under women's names. I am unable to determine whether the female owner is actually the owner-operator, or that her name appears on the ownership record so that one household can obtain additional subsidies by registering a two pond farm as two different farms. It is clear that several dozens of illiterate small and marginal farmers participated in the KAA survey because of their ink thumb prints placed in lieu of a signature.

[21] Land area is measured in hectares throughout this dissertation.

the appropriate unit area measure based on other information supplied in the survey. Less than 2 percent of the responses proved difficult in this regard. Nonetheless, each of the 518 responses was eventually successfully decoded with the appropriate units attached to numerical answers.

It is possible that the reported 1994 and 1996 average yields per hectare may be under or over stated and therefore biased. However, this does not seem to be widespread. Basic statistical cross tabulations reveal that only three farms report what look like outliers when comparing per hectare output and farm size. In all three cases, the farms reported extremely low output values. This may be a result of some form of crop disease that destroyed a large part of the crop. Alternatively, it may be the result of inadvertently attaching the incorrect units to the output response (i.e. kilograms as opposed to metric tonnes). Nonetheless, due to the large sample size of 518 farms, any bias is minimized as a result of aggregation. In addition, average yields per hectare classified by farm size are found to be consistent with the results of a more detailed survey of 82 shrimp farms.

Overall, in my view, there appears to be very little motivation for farmers to over or under estimate responses to any question in the KAA survey. The gravity of the Supreme Court order and local transparency of information seemed to maintain a degree of formality over farmers' responses to the EIF.[22]

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[22] There is a high degree of transparency as a result of the way in which EIFs were returned to the KAA. Each farmer filled out the EIF and gave it to the elected group leader for submission to the KAA. Each local farmer most likely realized that the elected group leader would be aware if there were any gross misrepresentations in their responses. It is possible that the entire group misrepresented their responses. However, this seems implausible as there does not appear to be anything to gain from this practice.

2.4 A Survey of 26 Villages

In addition to the 518 shrimp farms surveyed, inhabitants of local villages located adjacent to these farms were also surveyed. There are approximately thirty-eight well known villages and several dozen smaller *hamlets*[23] located adjacent to the major shrimp farming areas in fifteen coastal mandals in Nellore district, according to BFDA records. Some of these villages are coastal and located along the district's 164 kilometer stretch of beach, while others are inland and located adjacent to one of the district's five rivers.

Whereas the first challenge of this research (already discussed) was to collect data to characterize the Kandaleru shrimp farming sector, the second was to assess the impacts of shrimp farming on rural inhabitants. To address this important issue, villages located adjacent to shrimp farms were identified and then surveyed. Primary data collected via the KAA EIF survey enabled identification of fourteen creek-based villages located adjacent to Kandaleru river shrimp farms. Secondary data collected from BFDA enabled identification of sixteen sea-based villages located adjacent to sea-based shrimp farms. In total, only twenty-six of the thirty identified villages were surveyed.[24] This section presents the survey methodology used to assess the impacts of shrimp farming on these twenty-six villages.

2.4.1 The Survey Instrument

The survey of rural inhabitants used in this research is a hybrid of the community questionnaire methodology based on the Living Standard Measurement Study (LSMS) surveys of the World Bank and Rapid Rural Appraisal (RRA). The main objective of LSMS surveys is to collect data that can be used to assess household welfare, understand household behaviour, and to evaluate the effect of various government policies on the living conditions of the population (Grosh & Glewwe, 1995:3). The community questionnaire elicits

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[23] A *hamlet* is a small sub-division of a larger village. The hamlet is usually located very close to its associated village.

information regarding village infrastructure from community leaders and via group discussion. Specifically, it seeks to collect

> information on local conditions that are common to all households in the area. This format is typically used only in rural areas since local communities are easier to define than urban areas. The information covered by the questionnaire usually includes the...quality of health,...sources of fuel and water,...and agricultural conditions and practices (Grosh & Glewwe, 1995:6).[25]

RRA is described as an "iterative and exploratory team approach...that begins and moves rapidly beyond preliminary observations and semi-structured interviews with key informants" (Wolcott, 1995:109). Preliminary data help guide the construction of appropriate survey or questionnaire instruments which are employed to collect data in a limited amount of time. Bernard (1994:151) suggests that three months is the minimum time needed "to achieve reasonable intellectualized competence in another culture." While less than a week was spent in any given village surveyed, the survey team had at least five years of experience in these rural communities."[26] The survey of rural communities therefore employs methods of rapid appraisal, keeping questions short and focused around a few big issues (Spradley, 1979; Otto and Johnson, 1993:62). The specific details of this survey method are discussed in greater depth next.

2.4.2 Identifying Villages Located Adjacent to Creek-based Farms

Villages adjacent to shrimp farms are identified by a mapping or clustering technique.[27] Moreover, a particular village can be classified as belonging to a particular group or cluster of shrimp farms. The EIF asks respondents to report the name of the nearest village to their farm and the approximate distance in kilometers. Farms are therefore clustered according to

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[24] Only 24 of the 30 identified villages were surveyed due to a lack of time and resources.

[25] This is not to be confused with the LSMS Household Questionnaire which is a detailed survey of individual households in a given rural village.

[26] While I spent only six months in the rural Kundaleru region, the Fisheries Development Officers assigned to help me conduct my survey had several years of experience with many of the two dozen villages surveyed as part of this research.

this response.[28] In total, fourteen villages located adjacent to creek-based farms are identified. Thus, fourteen shrimp farming clusters are constructed.

Furthermore, each shrimp farm cluster is mapped by its distance from the Bay of Bengal.[29] Since the EIF asked each farm to identify the nearest village, it is likely that the village itself is roughly at the center of the shrimp farm cluster. We can therefore map each shrimp farm cluster by its "x" distance to the village and "y" distance to the sea. Table 2.0 presents the names of the villages identified by shrimp farmers, the average distance between each cluster and associated village, approximate distance from the Bay of Bengal, and whether the cluster and village falls on the northern or southern bank of the Kandaleru river. Figure 2.1 illustrates the approximate location of each village.[30]

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[27] This method of clustering farms by location follows Indian agriculture studies such as those found in Goel and Haque (1990).

[28] For example, farms self-reported as situated closest to Lingavaram village are referred to as the Ligawaram shrimp farm cluster.

[29] The distance between each shrimp farm cluster and the Bay of Bengal was determined by boating up the entire length of the Kandaleru river and marking the distance traveled from the river mouth to the village (in kilometers). In most cases, even with the village located up to two kilometers inland, we were able to identify each villages' beached boats. We used the boat landing area as a proxy for the center of the shrimp farm cluster.

[30] The location of each village necessarily identifies the approximate location of each shrimp farming cluster.

Table 2.0
Location of 1997 Creek-based Shrimp Farms Along the Kandaleru

VILLAGES IDENTIFIED BY SHRIMP FARMS	N*	AVERAGE REPORTED DISTANCE OF CLUSTER TO THE NEAREST VILLAGE (KM): "X"	APPROXIMATE DISTANCE OF CLUSTER FROM THE BAY OF BENGAL (KM): "Y"	LOCATION
1.Krishnapatanam	76	1.00	1	northern bank
2.Gummaladibba	3	1.00	2	southern bank
3.Epuru	44	1.00	10	southern bank
4.Venkatreddypalem	38	0.75	12	northern bank
5.Tirumalampalem	16	0.75	14	northern bank
6.Puddiparti	85	0.50	16	southern bank
7.Lingavaram	7	0.50	18	southern bank
8.Momidi	4	1.50	20	northern bank
9.Bestapalem	63	1.50	28	southern bank
10.Yeruru	20	1.50	32	southern bank
11.Palicherpalem	12	1.50	34	southern bank
12.Tikkavaram	72	1.20	42	southern bank
13.Kuttupattanam	9	1.20	44	southern bank
14.Tippaguntapalem	69	0.70	48	southern bank

source: Patil & KAA Database, 1997; N* is the approximate number of shrimp farms in each cluster.

2.4.3 Identifying Villages Adjacent to Sea-based Farms

Each sea-based shrimp farm was also mapped to the closest village to it.[31] In most cases, sea-based shrimp farms cover a much larger land and water spread area than the Kandaleru creek-based shrimp farms.[32] Sea-based farms are therefore adjacent to multiple villages as reflected in Table 2.1 below. The BFDA survey does not ask each farmer to specifically indicate which village is closest to it. Instead, the BFDA data sheets identify sea-based shrimp farms and list the names of villages adjacent to each farm. Sixteen villages located adjacent to sea-based farms are situated between the Buckingham Canal and the Bay of Bengal.

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[31] Sea-based farms are mapped using survey data collected by the BFDA.

[32] The average size of KAA farms is approximately 4.17 hectares (Patil & KAA Database, 1997a) as compared with the average size of sea-based farms which is 22.38 hectares (Patil & BFDA Database, 1997).

Figure 2.1

Villages Surveyed Along the Kandaleru River

note: number on map corresponds to the village with the same number as in Table 2.0. The map is not to scale; shaded areas represent water; Villages numbered 3,4,10 and 11 were not surveyed.

Table 2.1

Location of 1997 Sea-based Shrimp Farms Along the Bay of Bengal

VILLAGES ADJACENT TO BFDA SURVEYED SHRIMP FARMS	N*	AVERAGE REPORTED DISTANCE OF CLUSTER TO THE NEAREST VILLAGE (KM): "X"	APPROXIMATE DISTANCE OF CLUSTER FROM THE BAY OF BENGAL (KM): "Y"	TOTAL AREA COVERED BY FARMS (HA)
Venkateshwarapattapalem Venkannapalem Kothapalem Korathur	1	.5	.6	200
Ramachandrapuram Biscondapalem	7	.75	.75	524
Edurupattapalem	28	2	1	200
Pattapalem 1 Thattachettupalem Chennarayanapalem	38	1	1	518
Gavallapalem Mahalaxmipuram Pattapalem 2	17	1	2	388
Andalamapalem Thupillipalem Vadamedu	1	1	2	47

source: BFDA Database, 1996; N* is the number of shrimp farms in each cluster

The results of the coordinate x-y system of mapping shrimp farms to villages is a key component to the investigation of socio-economic and environmental impacts of shrimp farming on rural inhabitants. Clustering shrimp farms by identifying adjacent villages serves two purposes. First, it is now possible to survey those inhabitants living in villages adjacent to shrimp farm clusters. Second, from the results of village surveys and data on shrimp farm cluster characteristics, it is possible to identify which characteristics of shrimp farm clusters are statistically significant in explaining village survey responses regarding the farms' impact on their general livelihoods. The next section discusses the methodology employed to survey the villages corresponding to each creek-based and sea-based shrimp farming cluster.

2.4.4 Identifying Environmental & Social Impacts: Methodological Approach

A pre-tested questionnaire was used to identify and rank the major negative impacts of brackishwater shrimp aquaculture on the welfare of local populations inhabiting villages located adjacent to creek-based and sea-based shrimp farming clusters. Several questions adopted for the questionnaire were raised recently by NGOs and other concerned official bodies in Indian and international forums. Their overarching concerns stem from alleged negative impacts of the rapidly expanding brackishwater shrimp aquaculture sector on rural communities. The choice of villages surveyed arise from the EIF questionnaire responses which identify 14 creek-based villages and BFDA data that identify 16 sea-based villages located adjacent to major shrimp farming clusters.

The Pilot Survey

The village survey was piloted in December 1996 in Lingavaram village, one of the villages located adjacent to a shrimp farm cluster identified in the EIF questionnaire. The purpose of piloting the survey was three-fold: (1) to discover whether the survey methodology was appropriate given the characteristics of villages in this region; (2) to determine whether questions and answers were easily understood since a translator was needed; (3) to test whether group impact ranking was possible. The lessons learned from the pilot survey led to some modifications in the original methodology. First, group interviews were preferred to individual household interviews particularly because our presence in the village led to a large gathering at any given household. Second, interviews were open to both the male and female adults (who were in most cases the heads of the household). Third, additional questions were asked to elicit responses regarding the overall feeling toward the mid-December 1996 Supreme Court order.

Villages Surveyed

In total, twenty-six villages were surveyed. Sixteen of the total surveyed villages, or 62% were sea-based and located less than two kilometers from the Bay of Bengal. The remaining ten villages, or 38% of the surveyed villages were creek-based and located adjacent to Kandaleru Creek.[33]

Each of the twenty-six villages surveyed were chosen based on their proximity to previously identified shrimp farming clusters as discussed earlier. The sixteen sea-based villages were chosen after examining secondary data obtained from the Nellore BFDA which identifies the location of shrimp farming clusters. These villages were chosen due to their close proximity to at least one corporate shrimp farm. BFDA data reveals that corporate shrimp farms along the Bay of Bengal occupy the greatest land area adjacent to local villages. Thus, a sample of villages adjacent to large and corporate shrimp farms were identified and surveyed. The ten creek-based villages were selected from a total of fourteen possible villages adjacent to eleven major shrimp farming clusters. Each shrimp farming cluster was identified through the EIF survey. Table 2.2 provides descriptive characteristics of the surveyed villages near creek-based and sea-based farms.

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[33] There are two different types of shrimp farms operating in the Kandaleru region, sea-based and creek-based. Sea-based farms pump intake water from the Bay of Bengal and discharge effluent back into the sea or into the Buckingham canal. They are situated next to the sea. Creek-based shrimp farms pump intake water and discharge effluent into the Kandaleru river. These farms are situated near the creek.

Table 2.2
Summary Characteristics of Surveyed Villages

VILLAGE NAME	OCCUPATION*	POPULATION**	NUMBER OF HOUSEHOLDS**	AVG. SIZE
villages near creek-based farms				
Gummaladabba	fishing	1123	250	4.49
Lingavaram	farming	100	23	4.34
Venkatreddypalem	farming	88	20	4.40
Momidi	farming	120	32	3.75
Tikkavaram	farming	240	68	3.52
Krishnapattanam	fishing	510	95	5.36
Bestapalem	farming	1265	284	4.45
Puddiparti	farming	240	54	4.44
Thirumalampalem	farming	600	273	2.19
Tippaguntapalem	farming	64	24	2.66
villages near sea-based farms				
Venkateshwara-pattapupalem	fishing	290	90	3.22
Edurupattapupalem	fishing	624	161	3.87
Pattapalem 1	fishing	207	53	3.90
Thattachettupalem	fishing	1475	568	2.59
Chennarayanapalem	fishing	136	52	2.61
Ramachandrapuram	farming	300	121	2.47
Biscondapalem	fishing	100	30	3.33
Gavallapalem	fishing	198	48	4.12
Mahalaxmipuram	fishing	150	41	3.65
Pattapalem 2	fishing	252	114	2.21
Venkannapalem	fishing	180	60	3.00
Kothapalem	fishing	408	111	3.67
Korathur	fishing	322	95	3.38
Andalamala	fishing	415	97	4.27
Thupillipalem	fishing	648	148	4.37
Vadamedu	fishing	192	44	4.36

source: *denotes data from Patil & KAA Database, 1997; **denotes data from BFDA, 1996

Both villages near sea-based farms and those near creek-based farms are diverse in their occupation and size. Two of the ten villages near creek-based farms can be classified as primarily engaged in fishing. The primary economic activity of the remaining eight is agriculture. In contrast, fifteen of the sixteen villages near sea-based farms are involved in fishing. Only one is involved predominantly in agriculture. Sample villages also vary by size. The smallest village near creek based farms has a population of 64, whereas the largest village in this group has a population of 1,265. A similar range is found to exist for villages located adjacent to sea-based farms.

The Survey Teams

The research team consisted of two economists and two fisheries inspectors. The research team was split into two survey teams. Each survey team consisted of one principal investigator (an economist) and an inspector of fisheries assigned by the Brackishwater Shrimp Farming Development Authority (BFDA) to assist us.[34] The first team under the direction of Dr. Mohan Krishnan, Senior Fisheries Economist, CIBA surveyed the sea-based villages. The second team, under my direction surveyed the creek-based villages.[35] Both BFDA fisheries inspectors were familiar with the local villages, the local languages and dialects, village customs and traditions. They served as our guides and translators during the duration of the survey period. Transport, including Land Rovers and boats was provided by the BFDA and *Nav Bharat* Aqua Farms Ltd.

Village Questionnaire

The questions used for this survey were drawn from a wide body of literature addressing global concerns of rural based brackishwater shrimp aquaculture development.[36] This includes points made in the Supreme Court directive outlining the alleged negative social and economic impacts of shrimp farming in southeastern India. The major socio-economic and environmental concerns were distilled into six questions that specifically take into account local conditions and circumstances. The six principal survey questions asked include:

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[34] All necessary official protocol was followed. We obtained the necessary permits to conduct the surveys and to mobilize government staff to assist us from the Chief Executive Officer, BFDA, Nellore. Discussions took place with staff at PREPARE, one NGO active in the region. Although they provided invaluable insights to the concerns of the local population, they were unable to provide assistance in administering the survey. This turned out to be a blessing in disguise as their visibility in the villages we were surveying may have biased the responses.

[35] Financial support to carry out the sea-based village survey was provided by the Central Institute for Brackishwater Aquaculture. Financial support for the creek-based village survey was provided in part by the Rajiv Gandhi Foundation.

[36] Specifically, these questions were determined through discussion with local NGOs in the region, discussion with government officials involved in regulating brackishwater shrimp aquaculture, and through the growing literature on this subject. See Barraclough and Finger-Stich (1996), Clay (1996) and Hempel and Winthers (1997). A critical review of the literature is presented in Chapter One.

- Has aquaculture development hindered your access to the creek or beach?
- Are you experiencing drinking water problems in your village? Have your village wells become saline as a result of shrimp farm development?
- Has aquaculture development resulted in seepage of saline water into your agricultural lands? Has this reduced your crop yields?
- Has aquaculture development led to unemployment problems for you or your family?
- Has aquaculture development led to health problems for you or your family?; to animal populations in the village?
- Has aquaculture development hindered fuelwood or fodder collection?

The questions were kept short and to the point as this was thought to yield clearly understood and reliable answers (Otto and Johnson, 1993:62). Several follow-up questions to each core question were asked when clarification was needed.

The survey was designed to elicit two types of responses from male and female household heads in each village. First, it was necessary to see if a particular social impact was common to each village. In this regard, respondents were asked for a definitive "Yes" or "No" answer to each of the above six questions. Second, respondents were asked to rank the severity of each of the six social impacts on their overall well-being relative to each of the other impacts. Moreover, two additional questions were asked to gauge how different villages viewed the Supreme Court order and to see if they were overall better or worse off than five years ago.

- Are you and your family better or worse off than five years ago?
- Are you in favor of the recent Supreme Court order to ban shrimp farms from operating in the Kandaleru region?

These two questions were asked to yield a "yes/no" answer. Interestingly, less than 20 percent of the sample were aware of the Supreme Court judgment. Table 2.3 summarizes responses from the survey. Further analysis of these results are presented in Chapters 7 and 8 of this dissertation.

Table 2.3
Problems Identified by Coastal Farming and Fishing Communities Located Adjacent to Shrimp Farms in the Kandaleru Region, Nellore district, Andhra Pradesh.

% VILLAGES REPORTING PROBLEMS	Well Water Salinity	Access to Beach or Creek Blocked	Agricultural Land Salinity	Un/under employment	Poor Health	Fodder & Fuelwood
17 Fishing Villages	65% (11)	94% (16)	65% (11)	76% (13)	53% (9)	12% (2)
9 Farming Villages	66% (6)	33% (3)	89% (8)	11% (1)	0% (0)	89% (8)
All 26 Villages	65% (17)	73% (19)	73% (19)	54% (14)	35% (9)	38% (10)

Source: Patil and Krishnan (1997); note: the number of villages responding in the affirmative are in parenthesis. Note: The method used to assess each aggregate frequency is discussed in Chapter 7 of this dissertation.

Survey Method & Ranking Game

The creek-based survey team spent a minimum of one day in each village (in some cases several days) getting to know the concerns of that particular village community before conducting the formal survey. This enabled us to better guide our semi-structured discussions after conducting our formal survey. Of the ten villages next to creek-based farms, eight are identified as predominantly farming communities. Of the sixteen villages adjacent to sea-based farms, fifteen are identified as primarily fishing communities. A total of 9 farming and 16 fishing villages were surveyed. The sea-based survey team was able to survey multiple villages per day. This was possible as a result of exploiting the predictable daily pattern of male and female members of the fishing communities.[37]

The method of surveying each village was as follows. We identified the village *Panchayat* (Chief) and explained the purpose of our survey and the surveying method we intended to use. In almost all of the villages surveyed, the village Chief was known to the Fisheries Development Officer. In most cases, the Chief suggested that he would call a meeting of the village household heads that

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[37] Fishing communities in this region historically follow common daily routines. The nature of these routines make most adult males unavailable during the early mornings (when they fish) and adult females unavailable until mid-morning (they are usually involved in selling the catch). For greater discussion of the daily life of fisher-folk in Andhra Pradesh, please see BOBP (1988).

very afternoon. In some cases, the Chief informed us on which day to return to the village to conduct our survey. There was not a single case where we were denied permission to conduct our survey.[38]

Adult male and female heads of households were called together through the village Chief for an afternoon or early evening meeting.[39] The village Chief explained the purpose of our visit and asked the assembled village household heads for their cooperation. The survey itself was administered in two stages. First, through the Fisheries Development Officer who spoke the local language we asked the assembled village household heads a series of questions related to the alleged impacts of aquaculture on various socio-economic aspects of their lives. They answered each question with either a "yes" or "no" response and indicated this by raising their hands. In most cases the answers were close to unanimous across the group. This made it relatively easy to assign a "yes" or "no" response as an aggregate village response to whether a particular social impact was distressing their family or village community. When there were notable differences we counted each response and probed deeper by asking additional questions.

Second, the assembled household heads were asked to *rank* the relative severity of each impact. This was accomplished by asking each individual in the assembled group to indicate which impact was most important to them by raising their hand when it was announced. For example, we asked "please raise your hand if you think well water salinity is the most important problem you face from the six major problems discussed." Next, we inserted "agricultural land salinity/loss of agricultural crops" for "well water salinity" and repeated the question. We did the same for all six impacts. Next, we asked individuals to raise their hands when the second most important impact to their general well-being was called out. Again the above mentioned question was repeated for each impact. We used this line of questioning in six "rounds" until all six impacts

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[38] Village Chiefs most likely cooperated because it gave them a sense of importance to host a meeting called by a "foreigner" from an important organization with the Gandhi family name, namely, the Rajiv Gandhi Foundation.

[39] Household heads were available mostly during afternoon hours because most fishing/farming activities took place during the morning and evening when the temperature was cooler. Members

were ranked.[40]

The number of raised hands were noted for each question asked. Next, we repeated this for the next impact and so on. The results of this ranking game were later tabulated. Thus, a number *1* (most disrupting to the local population) to *6* (least disrupting to the local population) can be assigned to each question as it is the aggregated village response.

On average, we obtained a 32.1 percent turn out rate.[41] Only in one case did we not conduct the survey since the sample size was not large enough to conduct our survey.[42] Respondents included both males and females since in almost every case, the females accompanied the male household head to the village meeting either out of curiosity or as a result of the Chief's notification.[43] Thus, the team asked questions to a group of both adult males and females. To eliminate any possibility of gender bias, the overall village response was cross checked with female concerns by semi-structured interviews of women at their own homes later that day or the following day. Overall, the results appeared consistent.[44]

Aggregate Rank Order

The final tabulated response used in our analysis is an aggregated composite for each village.[45] This method of tabulation was adopted after running the more complicated pilot study which attempted to capture each individual response. The degree of complication introduced by tabulating each

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of predominantly fishing communities, however were found to follow a more predictable daily pattern.

[40] See Chapter 7, Appendix 7A for an account of the full ranking game for one of the 26 surveyed villages.

[41] See Table 7B.1 in Chapter 7.

[42] The number of households per village were known to us as a result of BFDA data. The number of households amongst our village sample varies widely from 20 to 568. In some of the smallest villages our assembled bunch numbered far less than ten individuals. In one of the larger villages, only a very few household heads turned up to our pre-planned meeting. We returned the following week to a larger gathering.

[43] This is a modification of the original pilot survey which called for the heads of households who happened to be in most cases, male.

[44] While no statistical cross-checking was possible, the overall concerns generated by the shrimp farming sector and relayed through respondents of the group interviews were shared by the women that we informally interviewed at their homes.

[45] We are unable to desegregate each individual response using this method. Therefore household level analysis cannot be used.

individual response did not warrant the use of this method. In addition, the type of data of interest was more necessary for the village level than for each specific household. This is particularly true since the population of each village surveyed was primarily employed in either fishing or farming based activities and therefore shared common concerns. Overall, in the pilot survey, we found that each individual response was over 90 percent similar to the overall tallied village response. Therefore, we deemed the overall village response level of reliability adequate to effectively represent each household and to carry through the objectives of this study.[46] However, differences in opinion between individuals in a common village were noted and further explored by the team.[47]

The aggregate rank order of each village impact was determined by tallying the responses for each village ranking game. The impact with the most *votes* received a rank of "1" and the impact with the least votes received a rank of "6". Using this method, it is possible to assign a rank for each impact facing each village.

2.4.5 Bias

It is important to identify possible weaknesses in the data as a result of survey bias. There are several possible problems associated with the village survey data well worth noting. First, the survey itself only focuses on possible negative externatilities associated with shrimp farming. Each of the survey questions are couched in the negative, thus leading respondents to think of the costs and not the benefits to brackishwater aquaculture. This method has been known to bias results toward a greater number of slightly negative responses in other impact studies than a more neutral line of questioning.[48] Second,

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[46] We are unable to separate out each individual response from our aggregated composite. This is a result of not identifying how each and every individual responded to each of our questions. We simply counted hands. This method yielded superior results for the time required as compared to the household level type survey used in the pilot study.

[47] It was not uncommon that only a few individuals in a fishing village would complain of a particular impact, say agricultural land salinity, whereas everyone else in the village reported that it was not a problem they faced. Upon further investigation, it was found that these particular individuals were predominantly farmers.

[48] Comments from participants at the 1997 Agricultural Economics Research Association conference held in New Delhi, India in September 1997.

respondents may have also disproportionately answered in the negative in order to receive compensation for damages. Villages in other regions were receiving compensation for damages caused by shrimp farms (i.e. well water salinity). Knowledge of this may have encouraged respondents to "cheat".

Third, all discussion between myself and the respondents took place through the Fisheries Development Officer, who served as an interpreter. Therefore any communication of information between the respondents and the interpreter was conveyed with his own personal or professional bias. Fourth, the ranking game proved tedious. Initially, the Fisheries Development Officer had a difficult time explaining the nature of the game to respondents. This required a lot of conversation between himself and myself which disrupted the flow of the game. However, after initiating the game in the first several villages, the ranking game ran much more smoothly.

Aggregate village responses were constructed in the analysis to avoid introducing excessive survey bias. However, aggregation imposes its own limitations. A detailed discussion on the method used to analyze these data is presented in Part III of this dissertation.

2.5 Shrimp Farm Production Data

2.5.1 Research Objectives

The purpose of gathering and analyzing production data is three-fold: to model, measure and explain total, pure technical and scale inefficiencies among sample shrimp farmers; to answer important questions regarding the economic behavior of shrimp farms; and to examine the impact of the shrimp farming industry on the rural labour market. The research examines whether there are economies of scale in this sector, whether environmental quality plays a significant role in determining farm efficiency, and whether rural inhabitants are benefiting from employment opportunities generated by shrimp farms. The research also provides relevant information to help guide the Indian government in its current efforts to effectively regulate shrimp production and ensure its sustainable development.

2.5.2 Background to Data Collection

To conduct this investigation of efficiency, more sensitive production data were collected from 82 shrimp farmers operating adjacent to Tikkavaram and Bestapalem villages in the Kandaleru region. These 82 farms amount to approximately 16 percent of the total 518 shrimp farm EIF survey responses returned to the KAA and 61 percent of the total number of shrimp farms located in these two clusters. These two localities were chosen for several reasons. First, farms in both shrimp clusters employ the full range of culture methods (i.e. from extensive to intensive farming). Second, there are a sufficient number of small, medium and large size farms to obtain a good representative sample of KAA farms. Third, the Tikkavaram cluster is located upstream from Bestapalem farms which enable investigation of whether location (a proxy for water quality) plays a statistically significant role in production.[49] Fourth, farms from both clusters used in the analysis operate on a two crop season unlike other clusters located downstream which culture three times per year.[50] Therefore the production cycle of farms in these two areas are relatively similar. Finally, this data set corresponds to the second crop cycle of 1996.

2.5.3 Methodology

First, the 518 KAA EIFs were sorted by clusters. The method of clustering farms together was based on the responses offered by shrimp farms as to the village closest to their farm. Farms clustered near Tikkavaram and Bestapalem villages were separated out from the rest of the sample. The EIFs for both Tikkavaram and Bestapalem clusters were sorted into three groups, namely, small, medium, and big farms (i.e. including both large and corporate farms). This was done to ensure that a representative sample of each size group would be

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[49] The hypothesis is that downstream shrimp farms are less efficient than upstream farms as a result of classic upstream-downstream externalities.

[50] Shrimp farm clusters located further downstream (closer to the Bay of Bengal) are able to culture three times a year because of less variability in water salinity. More upstream clusters are only able to culture twice a year due to inadequate salt content in the water as a result of monsoon rains draining into the top of the river from the nearby foothills.

included and that issues of scale could be investigated. Next fifteen farms at random were chosen from each size category for each of the two clusters. In total, forty-five farms were selected for each cluster and there were 90 farms selected in total for interview. However, due to limited time, a total of eighty-five shrimp farms were surveyed.[51] Of the 85 shrimp farms surveyed, data from 82 are used in the analysis.[52] Each farm was then identified by its address and KAA registration number from the EIF. Finally, data were collected at either the farm itself or at the household of the farmer.

Generally, larger farms had a records keeping office and a paid manager who provided the necessary production figures at the farm itself. Smaller farms tended to be operated by the owner who kept few written records. Nevertheless, in most cases, feed and seed purchase orders were available. In some cases, data on these two inputs were obtained via "recall" methods. Information on other production inputs were obtained through a series of questions asked by myself and conveyed through an interpreter. As the harvest season had just completed, a majority of the small and medium size farmers were interviewed at their households. Production figures were therefore easily communicated through recall.

2.5.4 Possible Bias of Recall Data

The questionnaire used to elicit data from shrimp farmers follows a standard written format used in most farm surveys (see Conway et al, 1987). This survey asks for details regarding basic farm, production and managerial characteristics used to culture shrimp in the bumper harvest season immediately preceding the survey. While written records were often available for large scale farmers, small and marginal farmers often kept no written records at all. Data were therefore solicited through mostly recall methods. Although there are well known reports of bias in farm level surveys based on recall data, de Corta & Venkateshwarlu (1992:109) suggest that production data concerning *major*

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[51] There was not a single case where the farm manager or owner-operator refused to answer our questions.

[52] Three questionnaires are incomplete and therefore left out of the analysis.

events are easier to collect by recall methods than regular seasonal events in India. As the second crop of 1996 yielded bumper profits, most shrimp farmers had little difficulty recalling the total amount of production inputs used.

2.5.4 Inputs, Farm Traits & Managerial Characteristics

Specifically, data on labour and capital inputs, farm specific traits and managerial characteristics were collected for each farm. Data regarding farm size and total amount of water spread area were provided by the returned EIFs. Data collected on land characteristics included total farm area in hectares, total waterspread area in hectares and the number of ponds per farm.[53] From these data a fourth land variable was approximated, average pond size. However, asking farmers for specific information again provided a way to double check the accuracy of their EIF responses. There was no significant variation from the EIF responses.[54]

Data on labour inputs include the average number of workers needed daily for each of the three phases in production: bund preparation, daily operation and harvest. Data were also collected on the number of days needed to prepare the ponds for culture, to grow the crop to exportable harvest size (approximately 35 grams per piece) and to harvest the crop. By combining these two sets of data it was possible to convert the reported daily labour inputs for each of the three production phases into total person-days per phase, total person-days per water spread area per phase, total person-days required overall and other variations.[55] In addition, farmers were asked to indicate what proportion of the total labour inputs used were hired locally.

Data on capital inputs include the number of aerators used per pond and whether the farm owned or jointly owned a water pump and the approximate size

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[53] In about half of the sample, the total area of the farm and total waterspread area were given in acres. These figures were converted into hectares. All analysis in this thesis is given on a per hectare basis. This is the most common unit of measurement used in shrimp culture studies.

[54] The Pearson correlation was strongly positive and significant at the one percent level.

[55] This is possible because we obtained data on the approximate number of days per phase. In some cases we base our analysis on certain assumptions. For example, corporate farmers revealed that they could harvest 1.5 to 2 ponds per day using phase 2 labour inputs. This research used the average figure in the analysis.

of that pump. Total feed inputs in kilograms and the total number of seed inputs purchased for the second crop cycle of 1996 were obtained. In addition, each farmer was asked to approximate how much of the feed was actually used. In most cases, each farmer said that all of the feed purchased was consumed. Farmers rarely purchased feed far in advance of the crop season or stored feed for future crops.

Data on farm specific characteristics included the origin of the feed purchased (i.e. foreign or domestic), the number of years the farm has been in operation (which was taken as a proxy for level of experience), whether the farm is owned or leased and whether the farm was a corporate entity (public or private limited) or individually/family operated. Data collected on managerial characteristics included the number of feeding times per day, the average stocking density per water spread hectare, the percentage of daily water exchange and whether the manager used tractor inputs or not in the bund preparation stage. From these data farms were categorized by several characteristics including size and technology type. An overview of the questions asked in the production data survey is presented in Appendix 2B.

2.5.5 Prices & Wages

Data on prices were not collected from the shrimp farmers by any formal survey method. Information on the purchasing price for seed, feed and aerator inputs was solicited from interviews with suppliers. Data on daily wages were collected via *ad hoc* discussions with farm hands. It became clear that the price vector of inputs faced by farmers had significant variation. This was a result of several different tied credit and input schemes made available to farmers of all sizes from seed hatcheries, feed mills and even processing plants. The nature of some of these contracts are discussed in later chapters. It is therefore difficult to draw any assumptions regarding the vector of prices faced by farmers in the 82 KAA sample.

2.6 Concluding Remarks

An information gap exists between the socio-economic and environmental problems occurring in local areas, and effective policy making. The gap between the rural environment and policy formulation and implementation exists due to a lack of comprehensive qualitative understanding of ground level realities and a lack of quantitative data to objectively examine a variety of hypotheses regarding industry-community interactions.

Both primary and secondary data collected from six months of field work in the Kandaleru region, Nellore district, Andhra Pradesh, India provide a first attempt at rigorously examining the efficiency of the shrimp farming sector and its socio-economic and environmental impacts on rural communities. Moreover, the research is extremely timely in that the current session of the Indian Parliament is debating claims made in favor of and in opposition to this industry. Overall, the farm level and production data are representative of shrimp farms in a specific Indian locality, comprehensive in nature, and unique and original. Secondly, the village impact survey are comprehensive in that they cover twenty-six villages in the region and indicative of what many villages throughout India's shrimp farming belt may be facing. Together, they provide the first comprehensive study on Indian shrimp farming and its impacts.

APPENDIX 2A

Appendix 2B

Table 2B.1
Primary Inputs and Descriptive Farm Characteristics

Production Input Variables	
LAND	total farm area in hectares
WSA	total water spread area in hectares
NOPNDS	total umber of ponds per farm
LAB1	total workers needed per day for bund preparation (phase 1)
LAB2	total workers needed per day for grow out period (phase 2)
LAB3	total workers needed per day for harvesting period (phase 3)
DUR1	average duration of phase 1 in days
DUR2	average duration of phase 2 in days
DUR3	average duration of phase 3 in days
SEED	total number of seed inputs used in 2nd cycle per farm (number)
FEED	total number of feed inputs used in 2nd cycle per farm (kilograms)
AERATORS	total number of aerators used in 2nd cycle per farm (number)
Farm Specific & Managerial Characteristics	
LOCATION OF FARM?	location dummy; 1=tikkavaram, 0=bestapalem;
SMALL FARM?	small farm dummy; 1=farms < 4 wsa; 0= otherwise
EXTENSIVE CULTURE?	technology dummy; 1=farms practicing extensive culture; 0=otherwise
TRACTOR INPUTS USED?	tractor use dummy; 1=farms using tractor inputs in phase 1; 0=otherwise
CHEMICAL INPURTS USED?	chemical use dummy; 1=farms using chemical inputs; 0=otherwise
FOREIGN FEED USED	manufactured feed dummy; 1=foreign, 0=local
CORPORATE?	corporate structure dummy; 1=corporate or private limited company; 0=otherwise
DO YOU OWN YOUR FARM?	ownership dummy; 1=land used by farmer is owned; 0=leased
YEARS OF EXPERIENCE?	number of years of operation (proxy for years of experience)
WATEXCHANGE %?	percentage of daily water exchanged
NUMBER OF DAILY FEEDING TIMES?	number of times shrimp are fed per day
Shrimp Aquaculture Output	
TOTAL FARM OUTPUT	total output of shrimp in kilograms

Chapter 3

The Growth & Development of the Kandaleru Shrimp Aquaculture Industry

3.0 Introduction

Very little comprehensive survey data exist on production characteristics and on managerial practices used to farm shrimp. This has made the study of shrimp farming somewhat vague and anecdotal. Moreover, country or regional data used to compare farm characteristics of shrimp farming nations are often based on broad estimates.[1] Nonetheless, they provide a reference point with which to begin investigations into global shrimp farming.

Case studies on Indian shrimp farming are particularly sparse in the literature, despite the fact that India has two well established government units promoting cultured shrimp production. General statistics on Indian shrimp farming come from one of two sources, the Central Institute for Brackishwater Aquaculture (CIBA) or the Marine Products Export Development Authority (MPEDA).[2] These organisations make statistical information publicly available through annual publications. Documents referred to as representative of country data are based on estimates drawn from local government publications. While general data exist at the local level, they are not appropriately documented at a regional or national level.[3] This is mostly as a result of a lack of co-ordination between local government offices and state and national government agencies.[4] In addition, as it is a rapidly evolving sector, locally collected shrimp farm data

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[1] For example, Rosenberry (1995-1998) annual publication, *World Shrimp Farming* is considered the most comprehensive publicly available global overview of shrimp farming. It is used as a reference source for every literature review on the subject of shrimp farming. The country statistics used in this publication (number of farms, total farm area, total water spread area, culture intensity, etc.), however are collected mostly from government fisheries departments. These data are usually broad estimates, at best. Future projections are based on the current country trends as observed by the author.

[2] MPEDA even has international representation in Singapore, Tokyo, New York, and Frankfurt.

[3] This became clear after reviewing local statistics collected from the local government agencies themselves.

[4] This is an opinion shared widely among CIBA's senior staff.

becomes quickly out of date.[5] Therefore, current year national statistics on farm level characteristics are often based on data collected several years before.

The most comprehensive regional study on Asian shrimp farm production to date, the NACA-ADB study has not yet been made publicly available. This is a farm level survey of seven Asian shrimp farming nations. However, basic summary production statistics from this study, which include India, have recently been published in Leung and Gunaratne (1997). The summary data on Indian shrimp farming made publicly available are roughly consistent with the 500 shrimp farm survey data collected as part of this research.

Modern shrimp farming cannot survive without the existence of supporting services such as seed hatcheries, feed mills, ice factories and processing plants. While the shrimp farming sector can be defined as *the collection of shrimp farms involved in the actual process of culturing shrimp,* the shrimp farming industry refers to the *shrimp farm sector plus the ancillary services that support the cyclical culture operation of farms.*[6] As a consequence of the union between shrimp farms and supporting services, global agri-business has a new member, the shrimp aquaculture industry.

In this chapter, the growth and development of the Kandaleru shrimp aquaculture industry between 1990 and 1997 is surveyed. This study draws on both primary and secondary data collected in the Kandaleru region. The methodology used to collect primary data is presented in detail in the previous chapter. Throughout this chapter, the primary 1997 Kandaleru data set is referred to as the KAA Database.[7] Secondary data are sourced by the particular local government agency from where they were provided.[8] Analysis of both together, serves as a comprehensive review of one of the most prolific shrimp farming

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[5] This is evident by the cumulative average annual growth rate of 19.5 percent exhibited by this sector in the Kandaleru region between 1993 and 1997. The latest available locally collected statistics were from 1993. 1997 data were collected by myself as discussed in the previous chapter.

[6] As discussed in Chapter One, Section 1.2.2, these definitions are provided by myself since no recognised definitions exist with respect to the shrimp farming sector and shrimp farming industry.

[7] Manipulations on this raw data are sourced as Patil & KAA Database (1997) throughout this thesis.

[8] Manipulations on raw secondary data (i.e. 1996 BFDA raw data) by the author are sourced as Patil & BFDA (1996). Incorrect manipulations of data, therefore fall squarely on the shoulders of myself.

regions in the most prolific Indian shrimp farming state, Andhra Pradesh. It also serves as the foundation to evaluating the economic performance of shrimp farms (discussed in Part II of this thesis) and in assessing the socio-economic and environmental impacts of the sector on rural inhabitants (discussed in Part III of this research).

The structure of the chapter itself is as follows: Section 3.1 identifies relationship between farm size, ownership status, production technology, factor inputs and shrimp output amongst Kandaleru shrimp farms. Section 3.2 discusses the growth and development of Kandaleru shrimp farms between 1993 and 1997. Section 3.3 traces the evolution, growth and development of ancillary services, that is, those services supporting shrimp aquaculture. Specifically, the impacts on off-farm employment are addressed in this section. Section 3.4 concludes.

3.1 1997 Kandaleru Shrimp Farm Characteristics

There are approximately 530 brackishwater shrimp farms located along the Kandaleru creek.[9] Together, they occupy 2,166 hectares in total area of which 1,675 hectares or 77 percent is water spread.[10] During the second culture cycle of the 1996 season, the 2,478 ponds in operation produced 1,788 metric tonnes of shrimp. This is an average of 450 kilograms of shrimp per pond or 620 kilograms of shrimp output per water spread hectare. The final 1996 season's harvest is considered the most successful in the sector's ten year history. Similar to other shrimp farming regions throughout India's coastal belt, Kandaleru shrimp farms vary significantly by size, intensity of production and ownership status. In this section, each characteristic is discussed in turn and relationships

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[9] According to the newly formed Kandaleru Aquafarmers' Association (KAA) registry, there are 518 registered members and no more than 530 farms in total along the Kandaleru creek. Cross sectional data were collected for 518 of the 530 shrimp farms operating along the Kandaleru creek, Nellore district, Andhra Pradesh. Data collected include each farmers' total land holding, total water spread area, total number of shrimp ponds, average yield during the bumper harvest of 1996 and during the disease year harvest of 1994, ownership status, and location (name and proximity of the nearest village).

[10] A water spread hectare denotes an area of one hectare capable of cultivating shrimp. It is the land area under water.

between them are compared and contrasted with the conventional wisdom on this sector.

3.1.1 Farm Size & Culture Area

On par with the national average[11], 79 percent of Kandaleru shrimp farmers produce on land holdings of less than five hectares. There are approximately 253 small and marginal farmers operating on land holdings of less than two hectares in area. This constitutes 49 percent of all Kandaleru shrimp farmers. In contrast, 108 farmers or 21 percent of all Kandaleru farmers produce on land holdings greater than five hectares. Of these 108 farmers, 43 percent of the sample, or 8 percent of all KAA farmers operate on 10 or more hectares of land. The number of shrimp farms per size category and the share of each size category is illustrated in Table 3.0.[12]

Table 3.0
1997 Kandaleru Shrimp Farms by Size of Land Holdings in Hectares

Size, S (HA)	*S<1* *marginal*	*1≤S<2* *small*	*2≤S<5* *medium*	*5≤S<10* *large*	*10≤S* *corporate*	*All*
No. Shrimp Farms	202	51	156	65	43	518
Share of Total (%)	39	10	30	13	8	100

source: Patil & KAA Database, 1997

In agricultural production, the total area sown is called the cropping area. The *culture area* in shrimp farming is equivalent to cropping area in agricultural production. It is the actual amount of land area used to culture shrimp, or water spread area. It is clear from Table 3.1 that the culture area of farms varies with farm size. Generally, farm size is positive and significantly correlated with culture area.[13] This suggests that larger farms have larger water spread or culture areas. In contrast, however, the proportion of total land area under culture—the land utilisation rate—declines with farm size.

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[11] MPEDA (1996).

[12] We draw upon the traditional Indian agriculture literature that define marginal farmers as those who own/operate less than one hectare of land; small farmers as those who own-operate between one and two (inclusive) hectares of land; medium farmers own-operate between two and five (inclusive) hectares of land; large farmers own-operate greater than five hectares of land (see Acharya, 1992).

[13] The Pearson correlation is 0.99 and statistically significant at the one percent level.

Table 3.1
1997 Kandaleru Average Farm Size, Culture Area & Land Utilisation Rate

Size, S (HA)	*S<1* *marginal*	*1≤S<2* *small*	*2 ≤S<5* *medium*	*5≤S<10* *large*	*10 ≤S* *corporate*	*ALL*
<u>1996 Averages</u>						
Farm Size	0.456	1.384	3.107	7.045	24.65	4.18
Water Spread Area	0.440	1.212	2.498	5.659	17.81	3.23
Utilisation Rate	0.975	0.885	0.805	0.804	0.802	

source: Patil & KAA Database, 1997

Farmers operating on larger holdings do not culture over the entire land area despite the near certainty of significant profits if they succeed. This is particularly true of the six largest Kandaleru based farms (land holdings greater than 100 hectares) which have an average utilisation rate of 0.63. There are two reasons why this may be the case.

First, larger shrimp farms tend to adopt a plantation style layout with management offices, a pump house, farm machinery storage facilities, a canteen, a scientific laboratory to test water quality and sometimes a guest house on the premises. Smaller farms, by contrast, do not support this kind of infrastructure. Therefore, it is perhaps not surprising that the proportion of land area used to culture shrimp on the largest farms is less than that of the smallest size farms. Medium size farms, however, on average do not subscribe to plantation style farming. Therefore, the fact that the utilisation rate is essentially constant between medium, large and corporate farms is perhaps reason to support a second view.

Second, risk aversion may play an important role here as a result of costly fixed and variable inputs used in more intensive farming methods adopted by large-scale farmers. Moreover, farmer uncertainty exists over the amount of shrimp output produced due to the unpredictable nature of disease outbreaks. Good farm management can reduce the probability of own farm pollution and therefore disease. However, because a common brackish water body is used by all farms in the region for both water intake and discharge, each farm assumes a certain amount of risk of water contamination or disease. Larger farms, therefore may face greater risk. Not only are they subject to the risk of upstream pollution out of their control, but also to risk assumed by adopting more intensive culture practices.

Overall, shrimp farmers of all sizes are believed to be constrained by a lack of technical and managerial knowledge necessary to ensure a successful crop. This notion is shared by other shrimp farming regions of the world too (Boyd, 1997). Interviews of farmers with land holdings of all sizes suggest that overall, KAA shrimp farmers tend to operate on a system of *learning-by-doing*. At least this is the impression communicated through semi-structured group discussions with KAA farmers. In fact, the results obtained from estimating inefficiency models in Chapters Five and Six suggest that shrimp farmers of similar size follow similar culture practices, however, with varying degrees of success. Some common production characteristics are presented in Section 3.1.3. In the next section, the relationship between land ownership status, land tenure status and farm size is discussed.

3.1.2 Land Ownership & Tenure Status

Of the 518 shrimp farms recognised as members of the KAA, 285 farmers or 55 percent reported that they own their farms, 81 farmers or 16 percent reported that they lease their farm land from private owners and 152 farmers or 29 percent reported that they received their land through a government land transfer or lease scheme for the purpose of shrimp farming. In Table 3.2, KAA farms are categorised by size and ownership status.

Table 3.2
Ownership Status by Size of Land Holding in Hectares

Size, S (HA)	$S<1$ *marginal*	$1\leq S<2$ *small*	$2\leq S<5$ *medium*	$5\leq S<10$ *large*	$10\leq S$ *corporate*
Land Owners	50	42	87	59	42
Share of Total Owned (%)	18	15	31	21	15
Share of Size Category (%)	25	82	56	91	98
Land Leased	0	9	69	6	1
Share of Total Leased (%)	0	11	81	7	1
Share of Size Category (%)	0	18	44	9	2
Land Transferred	152	0	0	0	0
Share of Total Trans.(%)	100	0	0	0	0
Share of Size Category (%)	75	0	0	0	0
ALL Shrimp Farms	202	51	156	65	43
Share of Total Farms (%)	39	10	30	13	8
Share of Size Category (%)	100	100	100	100	100

source: Patil & KAA Database, 1997

The data reveal that farm ownership status varies with farm size. Ninety-six percent of KAA farms operating on five or more hectares and 82 percent operating on an area between one and two hectares are owned by the operators. In the case of smaller farms, the owners are the individual farmer-operators. In the case of the larger farms, 71 percent are owned by wealthy shrimp farmers and 29 percent are either corporate entities with publicly owned shares or registered private limited companies.

Eighty-one percent of all shrimp farmers who leased land operate on holdings between two and five hectares. This is 44 percent of all medium size farmers. Of the 69 medium size farmers leasing land, a significant proportion are mostly non-natives of Nellore district. Their motivation for coming to the region and entry into the industry was in most cases entirely profit driven.[14] Generally, farmers of this size category came to the Kandaleru region in 1993, before the first major shrimp disease outbreak.[15]

All 152 farmers reporting that they received land via a government transfer scheme were entitled to this benefit due to their classification as members of one of India's Scheduled Castes or Scheduled Tribes (SCST).[16] Each one of these farmers operates on a total land area of less than one half hectare. The nature of the government transfer allotment for SCST is discussed in Chapter 4.

3.1.3 Production Characteristics

The amount of shrimp output produced is directly related to the input combination used in production. Similar to production of any agricultural crop, the quantity and factor proportions of inputs define the *intensity* of production or culture technique employed. Exact definitions of different culture techniques vary in the scientific literature. Most experts agree, however, that the intensity of shrimp production is generally a function of one capital input used in particular,

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[14] Based on semi-structured group discussions with KAA shrimp farmers in Spring 1997.

[15] This conclusion is supported by semi-formal group discussions with local shrimp farmers.

[16] For a good discussion of the scheduled castes and tribals in this region, please refer to BOBP (1993).

the number of seed inputs per water spread hectare, or *stocking density (SD)*. This relationship holds since the stocking density almost always defines the quantity and factor proportions of inputs required, especially feed inputs.[17] Based on the stocking density, farmers of all sizes adjust feed inputs accordingly. Table 3.3 defines four methods of shrimp culture based on the range of seed inputs employed. These definitions follow the available scientific literature on the subject of Indian shrimp farming.

Table 3.3
Five Culture Techniques Defined By Stocking Density

Culture method defined; intensity of production	*Stocking Density number of shrimp seed per water spread hectare*
Extensive	under 60,000
Modified Extensive	60,000 to under 100,000
Semi-Intensive	100,000 to under 200,000
Intensive	greater or equal to 200,000

source: CIBA (1997)

There is also agreement in the scientific literature that seed and feed inputs in tandem define the capital intensity of shrimp culture. The level of production intensity, can therefore be equated to the level of capital intensity. Less intensive culture is less capital intensive, while more intensive culture is more capital intensive. Therefore, the combination of five primary inputs: land in hectares of water spread area, labour in total person-days per water spread hectare, seed inputs or stocking density, feed inputs in kilograms of feed per water spread hectare and the number of aerators per water spread hectare directly influence the production of shrimp output in kilograms per water spread hectare.

Pearson correlation coefficients between fixed and variable inputs and output are presented in Table 3.4. The results generally support the above mentioned claims with respect to input use and culture intensity. There is significant positive correlation between stocking density and output, land and labour use per water spread hectare over the entire sample. As suggested earlier the stocking density is thought of as the principal input that determines the intensity of production. The data suggest that farms of greater (smaller) overall

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[17] This is confirmed by econometric estimation results presented in Part II of this thesis.

size adopt more (less) intensive production methods; that farms adopting more (less) intensive production methods use greater (fewer) land, labour and seed inputs per water spread area; and that farms adopting more (less) intensive production methods have greater (smaller) yields.

Table 3.4
Matrix of Major Production Input Correlation

N=83	OUTPUT	LAND	LABOR	FEED	SEED	AERATORS
OUTPUT	1.00					
LAND	0.25*	1.00				
LABOR	0.26*	-0.01	1.00			
FEED	0.85**	0.52*	0.22**	1.00		
SEED	0.83**	0.55**	0.21*	0.98**	1.00	
AERATORS	0.47**	0.37*	0.36**	0.40**	0.58**	1.00

*denotes statistically significant at 5 percent ;**denotes statistically significant at the 1 percent level. Source: calculations based on Patil & KAA Database, 1997

Generally, there is a positive relationship between average output per water spread hectare and farm size in shrimp farming (NACA, 1996). This relationship holds for Kandaleru farms too. The positive and significant Pearson correlation of 0.25 suggests that as farm size increases, the average output per hectare increases. The same relationship holds for seed and feed use per water spread hectare. More specifically, however, in addition to the amount and combination of inputs used shrimp yields can rise or fall depending on farm management practices. The relative importance of input quantities and their combination, and farm management practices on shrimp output per hectare for a sub-sample of 82 Kandaleru farms is examined in the next chapter.[18]

3.1.4 Partial Productivity Ratios

Partial productivity ratios are often used by agricultural economists to compare the productivity of various agricultural production systems. The observed static differences in the partial productivity ratios are generally

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[18] In December 1996 the Indian Supreme Court banned all shrimp farms using non-traditional methods of production (i.e. intensive production). Many Kandaleru shrimp farmers produce with non-traditional methods of production and therefore feared exposure. Due to their sensitivity and subsequent unwillingness to share production data via a formal questionnaire, 82 creek-based farmers of the 518 in the KAA were individually interviewed. The survey methodology is discussed in Chapter 2.

associated with differences in the use of modern industrial inputs and substitutes for land and labour. One notable difference from agriculture production theory with respect to shrimp farming is that labour requirements per fixed unit of land area increase with capital intensity (i.e. the intensive use of seed, feed and aerators).[19]

As very little farm survey data is available on Indian shrimp farming, few comparisons can be made against the KAA survey data. The partial productivity ratio for feed use, however, roughly follows the conventional wisdom of the sector. Sukumaran and Devraj (1995:318) suggest that extensive, modified extensive and intensive farms use on average, 495 kilograms, 701 kilograms and 13,376 kilograms of feed per water spread hectare respectively. This is roughly equivalent to that of the Kandaleru sample. Partial productivity ratios for five primary inputs used in culturing shrimp along the Kandaleru creek are presented in Table 3.5 below.

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[19] This result is not consistent with preliminary ADB-NACA results on labour use in Indian shrimp farm production. The ADB-NACA study quoted in Leung and Lokugam (December,1996) suggests that extensive shrimp farmers require 642 person-days per hectare while semi-intensive farms require only 472 person-days per hectare. This clearly suggests that more capital intensive production is less labour intensive. However, these data may not be reliable for several reasons. First, the published preliminary statistics do not distinguish between annual and seasonal labour inputs. Therefore, the per hectare averages are most likely incorrect. Secondly, it is clear from data presented on other countries, that there is little conclusive evidence to support the notion that labour inputs decrease with intensity. For example, data from Bangladesh, Indonesia, Philippines, and Viet Nam indicate the opposite result. Once the ADB-NACA data is made publicly available, the labour-capital trade-off can be examined more carefully.

Table 3.5
Partial Productivity Ratios

(average input quantities measured per water spread hectare)

culture intensity	output	land	labour	seed	feed	fcr	aerators
Extensive	510	0.803	138	46,562	523	1.06	1.4
Modified Extensive	686	0.816	147	67,964	859	1.41	1.6
Semi-Intensive	1,223	0.826	154	129,166	6,173	6.86	4.4
Intensive	2,188	0.783	196	262,500	14,190	8.94	6.2
Farm Average	793	0.807	149	84,444	2,831	2.84	2.5

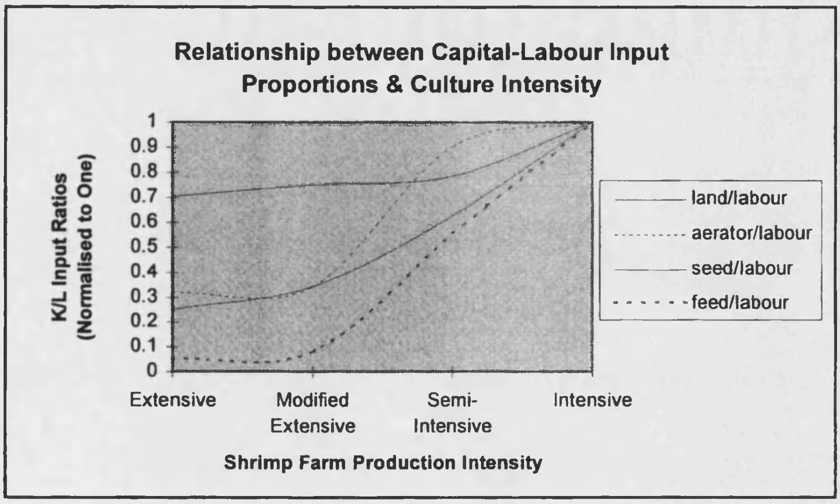
output is measured in kilograms per water spread hectare; land is the proportion of total farm area used for culture; labour requirements are measured in person-days per water spread hectare for one crop cycle in a two crop cycle year; seed inputs are the number stocked per water spread hectare; feed inputs are measured in kilograms per water spread hectares; fcr (food conversion ratio) is a special measure of feed efficiency and measured as the ratio between feed use and output; aerators are the number of oxygenating paddle wheels used per water spread hectare; All partial productivity ratios are measured for a single crop cycle lasting on average, approximately 144 days in duration, in a two crop cycle year; 82 farms in the sample.

Source: Patil & KAA Database, 1997b

3.1.5 Capital - Labor Input Relationships

An important indicator for assessing the production relationship between farms culturing at different intensities is the capital input-labour ratio. The capital-labour input ratios for each capital input, namely, seed, feed and aerators, increase with intensity of production (see *Figure 3.0)*. However, the ratios of aerators to labour and feed to labour both increase at an increasing rate between extensive and semi-intensive culture, after which they increase at a decreasing rate; the ratio of seed to labour increases at an increasing rate. The land-labour ratio increases at a decreasing rate between extensive and intensive culture after which it increases at an increasing rate. However, unlike the capital-labour ratios, it is relatively constant. This is not surprising since land is fixed across all inputs.

Figure 3.0



The above figure illustrates clearly that shrimp farming becomes more capital intensive as production intensity increases. The steep rise in the capital-labour ratios after modified extensive shrimp farming practices suggest that the amount of capital input per water spread hectare is increasing at a faster rate than labour requirements per water spread hectare. The relationship is more constant at lower levels of production intensity (i.e. extensive and modified extensive farming).

3.1.6 Production Intensity & Operational Cost

Operational costs are also known to vary with production intensity. It is unclear, however, whether larger farms are more cost efficient overall than smaller farms. Due to a lack of price data available for Kandaleru farms, this area of research is not explored in detail. However, some common relationships are found to exist with other studies based on average input prices.

A study by New et al (1990) of Thai shrimp farms suggest that the total operational costs per kilogram of shrimp output rise at an increasing rate with production intensity, ranging from extensive to semi-intensive culture and falls thereafter for farms engaged in intensive culture practices. While Indian farms operate using far less capital intensive technology than those in Thailand, a similar relationship may exist.[20] The ADB-NACA study for India suggests that the average cost of daily labour inputs per hectare on extensive farms amounts to approximately $9.4. Labour costs for semi-intensive farms amounts to $25.5 per hectare per day. Similarly, per hectare feed costs for extensive and semi-intensive farms amount to $5.9 and $4.9 respectively. Seed costs per thousand fry per hectare amount to $12.8 and $11.4 for extensive and semi-intensive farms, respectively. This is roughly consistent with the average price per thousand fry facing Kandaleru shrimp farmers.[21]

3.1.7 Summary

The summary of Kandaleru shrimp farm statistics presented in this section reveal several important findings. While almost 50 percent of all Kandaleru shrimp farms are owned and operated by small and marginal farmers, they control only 14 percent of the land area used to culture shrimp. Large and corporate farms, in contrast own or lease 54 percent of the land. The remaining 32 percent of total water spread area used to farm shrimp is occupied by medium size farms. Second, the more intensive methods of production produce higher per hectare shrimp yields. However, not without concerns for the environment. Feed efficiency (as defined by the feed conversion ratio in Table 3.5), for example, declines with production intensity. This necessarily means that uneaten feed settles to the pond bottom where it can degrade the quality of the pond. The final consequence is pollution of both the on-farm and off-farm aquatic environment. Finally, capital-labour input ratios increase over farm intensity

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[20] This is determined by comparing production data of Kandaleru shrimp farms with the general production data of Thai farms presented in Leung and Lokugam (1996) overview of the ADB-NACA study.

[21] This amounts to roughly 0.38 Indian Rupees per seed using the average 1996 Dollar-Indian Rupee exchange rate. Input price data were not collected in the KAA sample farm survey. However, average input price data shared informally by shrimp farmers suggest that the price per individual seed is approximately 0.35 Indian Rupees.

levels. This clearly indicates that shrimp farming becomes more capital intensive as farm size increases. In the next section, the pattern of growth and development of the shrimp farming sector in Nellore district between 1993 and 1997 is examined.

3.2 Growth & Development of Kandaleru Shrimp Farming

Brackishwater shrimp aquaculture has rapidly grown along the Kandaleru creek since the first farm began operation in 1987.[22] Encouraged by the possibility of high economic returns, farmers rapidly entered this rural based sector. Since the 1992-1993 season, the total number of shrimp farms operating in this region increased from 254 to approximately 530 in the 1996-1997 season.[23] This corresponds to a cumulative average annual growth of approximately 19.5 percent over four years. Similarly, the total area used to culture shrimp almost doubled from 1,242 hectares to 2,166 hectares over the same period. This amounts to a healthy 13 percent annual rate of growth. The number of corporate farms grew at a cumulative average annual rate of 50 percent, from six in 1993 to thirty-one in 1996.

3.2.1 Output Growth

Although shrimp farmers have enjoyed healthy profit and a positive average annual growth since 1987, the Kandaleru shrimp industry suffered a serious setback in 1993-1994 when average output per hectare dropped from approximately 400 kilograms in 1992 to 165 kilograms in 1993 as a result of crop disease.[24] At the end of this season, at least four corporate shrimp farms declared bankruptcy as a result (BFDA, 1996).

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[22] 1987 is reported by the BFDA as the year when shrimp farming first became popular along the Kandaleru river.

[23] 1993 statistics are based on a 1994 BFDA survey (see BFDA, 1994); 1997 statistics are based on primary KAA survey data (see Patil & KAA Database, 1997).

[24] There is much debate as to the source of the "White Spot" disease which destroyed a majority of the 1992-1993 season's harvest. Interviews of farmers suggest that the disease was a result of contaminated seed purchased in bulk from Thailand that year. Industry experts, however, claim

Farms of all sizes posted financial losses, forcing the less financially secure to exit the sector. Although data on the specific number of farms that exited the industry by size of land holding is unavailable, primary survey data does enable analysis of the characteristics of new entrants after 1994. Overall, the share of larger farms dropped while the share of marginal farms rose over the period (see Table 3.7).[25]

Table 3.6
Average Output by Farm Size during 1993/4 & 1996/7 Season

Size, S (HA) *Output (Kg/HA)*	$S<1$ *marginal*	$1\leq S<2$ *small*	$2\leq S<5$ *medium*	$5\leq S<10$ *large*	$10\leq S$ *corporate*	*ALL*
1992 Average Output(a)	*NA*	*NA*	*NA*	*NA*	*NA*	*400**
1993 Average Output(b)	*110.9*	*64.8*	*86.5*	*465*	*515*	*165*
1997 Average Output(c)	*333.3*	*404.7*	*537.0*	*821*	*1,474*	*558*
avg. annual growth rate	*32 %*	*59 %*	*57 %*	*15 %*	*27 %*	*36 %*

source: (a) 1992 BFDA estimates; (b) BFDA Database, 1996; (c) Patil & KAA Database, 1997

Output growth per water spread hectare rebounded from its 59 percent drop between 1992 and 1993. Between 1993 and 1997, shrimp output (in kilograms per water spread hectare) grew at approximately 36 percent annually. The average annual output growth rate is largest for small and medium size farms at an average of approximately 56 percent, and smallest for large and corporate farms. This suggests perhaps (i) a steep learning curve for the smallest farms, enabling them to culture shrimp more efficiently; (ii) smaller farms generally boosted production intensity over the period to yield higher per hectare output; or (iii) a combination of both factors. As production data for both years in not available, it is not possible to explore this further. However, results presented later this thesis suggest that it is most likely a combination of both factors. Small and marginal farmers with more years of experience were not found to be any more efficient than less experienced farmers of the same size (see Chapter 5).

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that the disease was most likely due to poor pond management (CIBA, 1996). The White Spot disease spread rapidly as the Kandaleru Creek serves as both the source of clean water intake and effluent discharge.

[25] Farm size is a good proxy for production intensity. This conclusion is based on the significant positive correlation between farm size and quantities of capital inputs (i.e. seed, feed, etc.) used in production (see Section 3.1.3 presented earlier in this chapter).

3.2.2 Farm Size & Growth

Table 3.7 illustrates that since 1993, the share of marginal farmers, those farmers operating on less than one hectare of land increased; the share of small farmers, those farmers operating on land holdings between one and two hectares dropped significantly; the share of medium scale farmers, those farmers operating on land holdings between two and five hectares stayed relatively constant; while the share of large private and corporate farmers, those holding greater or equal to five hectares of land dropped. The number of shrimp farms grew at an cumulative annual rate of approximately 19.5 percent over the period with marginal, medium, large and corporate farms growing at an annual rate of 47 percent, 18 percent, 8 percent, and 9 percent, respectively. The growth rate of small farms was negative 2 percent over the period.

Table 3.7

Kandaleru Shrimp Farms & Share of Total by Size of Land Holding

Size, S (HA)	$S<1$ *marginal*	$1 \le S<2$ *small*	$2 \le S<5$ *medium*	$5 \le S<10$ *large*	$10 \le S$ *corporate*	*ALL*
1997 Shrimp Farms	202	51	156	65	43	518
1993 Shrimp Farms	43	56	78	47	30	254
1997 Share (%)	39	10	30	13	8	100
1993 Share (%)	17	22	31	18	12	100
% Change in Share	+22	-11	-1	-5	-4	
avg. annual growth rate	*47 %*	*-2 %*	*19 %*	*8 %*	*9 %*	*19.5 %*

source: Patil & KAA Database, 1997

Overall, average farm size and average water spread area fell while the land utilisation rate rose over the period (see Table 3.8). In 1993 the average size of all 254 farms was 4.92 hectares of which 73.9 percent or 3.54 hectares were water spread. In 1997 there were 518 farms with an average size of 4.17 hectares. 77.5 percent or 3.23 hectares were water spread.[26] Thus, the land utilisation rate grew at an average annual rate of 3.6 percent over four years.

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[26] Average farm size and average water spread area fell over the period because the majority of the new entrants to the industry were small and marginal farmers.

Table 3.8
Average Farm Size, Water Spread Area & Land Utilisation Rate; 1993 & 1997

Size, S (HA)	*S<1* *marginal*	*1≤S<2* *small*	*2 ≤S<5* *medium*	*5≤S<10* *large*	*10 ≤S* *corporate*	*ALL*
1997 Averages						
Farm Size	0.456	1.384	3.107	7.045	24.65	4.18
Water Spread Area	0.440	1.212	2.498	5.659	17.81	3.23
Utilisation Rate (%)	97.5	88.5	80.5	80.4	80.2	77.5
1993 Averages						
Farm Size	0.524	1.205	3.06	6.56	17.0	4.92
Water Spread Area	0.386	.916	2.47	4.89	12.20	3.64
Utilisation Rate (%)	73.4	76.7	80.7	75.1	70.5	73.9

source: Patil & KAA Database, 1997

3.2.3 Conclusions

The results presented in this section yield four important findings. First, the rise in the number of marginal farm holdings between 1993 and 1997 suggests that shrimp farming has low barriers to entry for marginal farmers (see Table 3.7). This is most likely due to the less capital intensive nature of small farm production, the local availability of key inputs such as feed and seed which keep variable costs relatively low and perhaps most important, access to land and the availability of credit via government land transfer and subsidy schemes.[27]

Second, the net drop in the number of small farms over the period suggests that either a proportion of small farms exited the industry or increased their land holding and moved to the medium size farm category (see Table 3.7). This first possibility is particularly plausible since this farm size group suffered from the lowest average output during the 1993-1994 season (see Table 3.6). However, the same result taken with the relatively constant proportion of medium size farms over the period suggest that the most successful small farms could have increased their land holding over the period. This seems particularly plausible since of the 56 small farms, 31 reported no harvest for that crop season

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[27] This is discussed in detail in Chapter 4.

while the remaining 25 farms reported an average yield of 145.2 kilograms per hectare.[28] The most likely explanation, however, is a combination of both factors.

Third, there have been many attacks on the shrimp farming sector by social activists, alleging that it does not benefit the local community and especially the poor. Survey data suggests that shrimp farms operating on the smallest land holdings (less than one hectare) are owned and operated by inhabitants of local villages. In fact, of the 202 farms less than one hectare in size, 150 of them, or 29 percent of all KAA shrimp farms were operated by members of the SCST community who are considered the poorest among those inhabiting the Kandaleru region (Patil & KAA database, 1997; BFDA, 1997). It is clear that the poor and socially excluded members of society are not restricted from farming shrimp. It is less clear, however, to what extent they are able to compete with their richer neighbours.

Finally, the growing land utilisation rate in each category over the period (with the exception of medium size farms which are relatively constant) suggests that farmers of all sizes are perhaps becoming more comfortable with existing production technology and thus use land inputs more fully (see Table 3.8). This suggests profit maximising behaviour. It may also suggest a greater knowledge stock available on shrimp culture which enable farmers to culture with a greater degree of control over disease.

3.3 A Survey of Ancillary Services in 1997

Since the advent of shrimp farming in the late 1980s, ancillary services have rapidly developed as essential support services to the shrimp farming sector. However, very little research concerning the growth and development of ancillary services is available. Characteristics of firms providing supplementary services to the shrimp farming sector have not been formally analysed to date. This research, therefore, provides the first attempt at explaining the significant role that they play.

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[28] The standard deviation is 0.10

Although it appears that the growth and competitiveness of support services may benefit local shrimp farmers by lowering overall production costs, it is less clear what overall impact ancillary services are having on the rural economy and on rural inhabitants in particular. This is particularly true with respect to employment. The analysis presented in the next two sections trace the growth and development of ancillary services in context of the district's estimated demand for these services. Section 3.3 surveys the characteristics of ancillary services in operation as of January 1, 1997. Sub-section 3.3.1 surveys the number of firms and total productive capacity available in each of the four supporting industries. In Sub-section 3.3.2, the total district demand for seed and feed are assessed. This assessment is based on proportionally scaled estimates of sample survey data to the district level. Thus, the input requirements of 1,258 farms operating in the district are in the same proportion as the input requirements found to characterise the 518 KAA farms by size category. Sub-section 3.3.3. examines the demand for labour in ancillary services.

The final section of this chapter, Section 3.4 surveys the growth and development of ancillary services between 1990 and 1997. Sub-section 3.4.1 and Sub-section 3.4.2 trace the pattern of growth before and after the 1994 disease outbreak, respectively. Finally, Sub-section 3.4.3 offers some concluding remarks.

3.3.1 Productive Capacity of Ancillary Services

The major ancillary services that developed in Nellore district to support the shrimp farming sector include seed hatcheries, feed mills, processing plants and ice factories. Brackishwater shrimp farming requires three principle variable inputs for production, namely, shrimp seed, feed and labour. Processing plants are needed to sort shrimp by size and package them in post-harvest activities. Flaked ice is needed for safe storage and transportation of shrimp from the farm gate to processing plants where they are block frozen for export.

According to unpublished BFDA survey data, in 1996, 33 seed hatcheries, 14 feed mills, 8 processing plants and 24 ice factories were providing essential inputs and services to Nellore district's shrimp farming sector (see Table 3.9). The total annual productive capacity for seed hatcheries was 2,380 million seed. The 14 feed mills, offering foreign and domestic brand feed, were aggregately capable of producing 78,000 metric tonnes of feed per year. The 24 ice factories could produce 285 metric tonnes of block and flaked ice annually, if needed. The 8 processing plants had the capacity to process and package 24,000 metric tonnes of shrimp.

Similar to other agri-businesses, there are several ancillary services that have common corporate owners. In Nellore district, there are 6 integrated units selling both major inputs such as seed and feed and post-harvest support services, ice and processing. Each company owning and operating integrated units were also involved in corporate style intensive shrimp farming. On average, integrated units had higher average productive capacity than non-integrated units for seed hatcheries and feed mills. The productive capacity of processing plants for integrated units was slightly smaller than non-integrated firms.

Table 3.9
Capacity of Ancillary Services in Nellore District

Ancillary Services	**Firms**	**Mean Capacity**	**S.D.**	**Min**	**Max**
Seed Hatcheries	33	72	42.9	30	200
Integrated Units	18 percent	103	65.3	40	200
Feed Mills	14	5,571	2,680	2,000	10,000
Integrated Units	43 percent	7,666	2,065	5,000	10,000
Processing Plants	8	3,000	963	2,500	5,000
Integrated Units	75 percent	2,750	612	2,400	4,000
Ice Plants	24	11.8	2.9	10	20
Integrated Units	25 percent	NC	NC	NC	NC

source: Patil & BFDA Database, 1997; note: NC denotes not calculated due to poor data

The question remains, what proportion of the productive capacity of these services were required by shrimp farmers during the 1996-1997 production cycle? This is discussed next.

3.3.2 Seed and Feed Requirements in Nellore

According to the latest official statistics, there were approximately 1,258 shrimp farms operating in Nellore district in 1996 (CIBA, 1997) of which approximately 39 percent or 491 were marginal farms, 10 percent or 126 were small farms, 30 percent or 377 were medium farms, 13 percent or 163 were large farms, and 8 percent or 101 were corporate type farms (see Table 3.10).[29] Simulation experiments suggest a total seed input requirement of approximately 763 million seed during the second crop cycle in 1996.[30] The yearly district-wide seed requirement is estimated to be approximately 1,526 million seed.

Assuming that each farm purchased seed from one of the 33 seed hatcheries operating in the district, Nellore district's seed hatcheries operated at approximately 64.1 percent of the annual production capacity of 2,380 million seed. Following the realistic assumption that marginal farmers purchased natural seed from local fishers and not from seed hatcheries we conclude that 1996 hatchery seed demand in Nellore district was 1,524 million seed which implies district hatchery production at 64.0 percent of annual production capacity. However, since farmers from adjacent districts most likely purchase seed from one of the Nellore based hatcheries, this figure is most likely an underestimate.

Table 3.10
Average Seed & Feed Inputs per crop by Size, S in Nellore district

Farm Size, S (HA)	# Farms*	Avg. number of seed inputs per farm of size, S	Avg. feed inputs (kgs) per farm of size, S
S<1	491	1,500	120.0
1≤ S< 2	126	48,600	472.5
2 ≤ S< 5	377	141,820	2,036.4
5≤ S<10	163	381,439	9,108.7
10 ≤ S	101	6,342,833	329,163.4
District Total	1,258	Seed Inputs: 763,126,930	Feed Inputs: 35,616,399.3

source: Patil & KAA Database, 1997b; Patil & BFDA Database, 1997; *determined by scaling the total number of farms in Nellore district by the percentage of farms of each size for our 518 KAA shrimp farm sample.

According to both large and small scale shrimp farmers, the 1994 viral outbreak was a result of diseased seed inputs imported from Thailand.[31] Besides small and marginal farmers who purchased natural seed collected locally, the majority of the hatchery seed inputs were purchased and imported from

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[29] Percentages are based on farm size breakdown for the 518 shrimp farms in the KAA.

[30] Estimates are based on KAA Data scaled appropriately.

[31] Semi-structured interviews of KAA shrimp farmers of all sizes suggest this to be the case.

Thailand.[32] In 1996, with seed readily available domestically, shrimp farmers purchased locally produced hatchery seed as a result of cheaper prices and the possibility of testing shrimp seed for contamination before purchase. While farmers were wary of imported foreign shrimp seed as a result of the 1994 viral outbreak, seed produced domestically by foreign firms was acceptable.

Feed is the second most important variable input after seed but the most expensive variable input. Despite the lower price for domestic feed, feed produced by foreign firms was considered superior because of its alleged higher quality. Approximately 71.1 percent of KAA sub-sample farmers purchased foreign brands for 1996 production (Patil & KAA Database,1997b). In 1996 the district's feed mills had a joint annual capacity of 76,000 metric tonnes. The demand for feed among the district's shrimp farms in 1996 is estimated at 71,232 metric tonnes.[33] Assuming that all feed requirements were purchased from one of the district's fourteen feed mills, Nellore district farms consumed 93 percent of the total productive capacity of feed mills in the second crop cycle of 1996.[34]

3.3.3 Labour Demand & Off-farm Employment

For the Kandaleru region, ancillary services have provided employment opportunities for both skilled and unskilled workers. It is estimated that the thirty-three seed hatcheries employ approximately 1,650 workers; the fourteen feed mills employ approximately 840 workers; the eight processing plants employ approximately 1,200 workers; and the sixteen new ice plants employ approximately 400 workers.[35] In total, over 4,000 jobs were created from the development of ancillary services in Nellore district alone. While it is clear that there are strong direct employment opportunities associated with the

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[32] Prior to 1994 there were only four seed hatcheries operating in Nellore with a total overall capacity of 240 million seed which was exhausted given the 600 plus farms in the district at that time.

[33] The total feed input requirement for all Nellore district shrimp farms during the second crop cycle in 1996 was approximately 35,616,400 kilograms. Assuming that farmers used similar combination of inputs for the previous crop cycle, annual district demand for feed was most likely around 71,232,800 kilograms or 71,232 metric tonnes.

[34] This figure is perhaps slightly higher when considering that adjacent coastal district farms purchased feed from these mills too. However, because of the strong preference for foreign feed, we believe that mills were operating on average at less than 50 percent of capacity.

[35] Data on employment levels was collected by interviewing managers of different ancillary units in Nellore, the capital of Nellore district.

development of ancillary services, it is less clear as to whether these supporting industries are of any benefit to the local *village* economy. Further research not attempted in this thesis is required to answer this question.

Off-farm employment opportunities are not only available for those individuals engaged by one of the district's supporting industries. Local coastal villagers, especially women and children have supplemented family income by collecting shrimp seed from near-shore coastal waters and by selling them to shrimp farmers through a well organised distribution network.[36] Group interviews revealed that women were the primary agents in this economic activity, serving as wild seed collectors and as middle-agents for shrimp farms. Women and children of sea-based villages collected shrimp seed from near shore waters in season. According to the local school teachers in Krishnapatnam village, during the peak season, most school age girls missed school in order to collect shrimp fry.[37]

Once collected, the fry were sold on a per piece basis to a village agent, also female, who sorts the fry by variety.[38] The fry were separated and stored in earthen pots. Each day the village agent sold the shrimp seed to local shrimp farmers at a previously negotiated price. From the interviews it became clear that the particular village middle-agent operating in Krishnapattnam also served several other nearby villages in the area. This was true of other middle-agents operating in different villages in the Kandaleru region. These findings are also supported by FAO studies in Bangladesh and West Bengal, India (see BOBP, 1994; BOBP, 1993).

After the first crop cycle in 1996, village seed collectors complained of a lack of employment opportunity. There appeared to be a low demand for natural seed. This was most likely a direct result of the greater demand for hatchery seed

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[36] It was observed that almost every household in sea-based villages owned a shrimp fry net. The nets were visible leaning against the sides of huts throughout the village.

[37] Based on discussions with village school teachers in Krishnapattanam village.

[38] Both White shrimp fry and the highly demanded Black Tiger variety are collected from coastal waters. The agent is known to be skilled in determining the variety of the shrimp fry collected on inspection.

by shrimp farmers and the declining availability of natural seed as a result of over fishing.[39]

3.4 Growth & Development of Ancillary Services (1990-1997)

Prior to 1990 most small and marginal scale Kandaleru shrimp farmers purchased seed collected by the region's fisher community. They also prepared their own shrimp feed from indigenous materials. Medium, large and corporate farms imported seed and pellet feed from Thailand and Taiwan. In 1992-1993, this balance began to shift slightly as corporate farms began purchasing seed and feed produced locally by multinationals who built and operated seed hatcheries and feed mills. By the 1996 season almost all farmers operating on land areas over two hectares were purchasing seed produced locally from seed hatcheries (Patil & KAA Database, 1997b). Only the smallest farmers continued to purchase seed from local fishers who collected shrimp fry from the near shore coastal waters of estuaries and made their own feed from village resources.[40]

Between 1990 and 1997, the region had witnessed rapid growth and development of supporting services to the shrimp farming sector.[41] Aside from eight ice plants which operated in the region as a support to the local fishing port at Krishnapatnam in 1990, the remaining 16 of 24 ice plants, 8 processing plants, 14 feed mills and 33 seed hatcheries were built since 1993 to supply shrimp farms with necessary inputs. According to unpublished BFDA data collected from the region, 4 seed hatcheries, 13 feed mills, 3 processing facilities and 6 ice plants were first constructed and ready for operation by 1993 (see Table 3.11). Between 1993 and 1997, seed hatcheries grew at an average annual rate of 69

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[39] There is growing concern over the wild stock population of shrimp. The FAO's Bay of Bengal Program in conjunction with environmental NGOs have implemented outreach programs to educate fisher-folks to the dangers of over fishing shrimp fry from coastal waters. FAO BOBP suggest that while supplemental income is earned by women and children from fry collection activities, fewer mid to large size shrimp are ultimately being caught by the men-folk because less fry are able to grow to maturity in the wild. Overall, shrimp caught in the wild at a larger size are more valuable than the per piece price earned by catching fry. In addition, environmental NGOs fear exploitation of this resource.

[40] Based on semi-structured interviews of shrimp farmers of all sizes.

[41] The shrimp farming sector in conjunction with the supporting services define the shrimp farm industry.

percent; the number of processing plants and ice factories both grew at an average annual rate of 28 percent; while feed mills only grew at 2 percent per year over the period. While the average annual cumulative growth of all supporting services over the period was a healthy 31 percent, annual growth rates seem to follow the successes and failures of the shrimp farming sector.

Table 3.11
Growth Pattern of Ancillary Industries in Nellore district

Ancillary Industries	1990-1991	1992-1993	1994-1995	1996-1997
Total Seed hatcheries	0	4	30	33
New Additions	0	4	26	3
Total Capacity[1]	0	500	2,250	2,380
Total Feed Mills	0	13	14	14
New Additions	0	13	1	0
Total Capacity[2]	0	76,000	78,000	78,000
Total Processing Plants	0	3	6	8
New Additions	0	3	3	2
Total Capacity[2]	0	10,000	19,000	24,000
Total Ice Factories	8	14	22	24
New Additions	0	6	8	2
Total Capacity[3]	NC	80	180	285

source: CIBA (1997); notes: years in parenthesis indicate the year of completion; [1]million of PL20 seed; [2]metric tonnes; [3]metric tonnes, capacity is calculated for only those factories built primarily as a result of shrimp farming.

3.4.1 1994 Shrimp Disease & Its Impact

The 1994 shrimp disease that wiped out that season's harvest affected the healthy growth pattern of ancillary industries in Nellore district, especially seed hatcheries, ice plants and processing plants. Construction of new seed hatcheries and construction on existing half completed hatcheries post December 1994 slowed significantly. There were no additional feed mills constructed and only two additional processing plants and ice plants constructed post December 1994. Those plants in operation prior to the second crop culture period in July/August 1994 provided necessary seed inputs and were operating at near capacity. Because of the dramatic decline in shrimp output that year, ice and processing plants (post-harvest supporting services) operated far below maximum capacity.[42]

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[42] These claims are supported by semi-formal interviews of managers engaged in post-harvest activities.

The growth rates of supporting services pre and post 1994 season's disease are presented in Table 3.12. The results suggest that prior to the 1994-1995 season, each supporting service was growing rapidly.[43] After the disease, growth slowed considerable across all ancillary industries.

Table 3.12
Average Annual Growth Rates of Firms by Type & Capacity

Ancillary Industries	1993-1995 pre-disease	1995-1997 post-disease	1993-1997
Seed Hatchery growth rate, %	*174*	*5*	*69*
Hatchery Capacity growth rate, %	*112*	*3*	*48*
Feed Mill growth rate, %	*89*	*0*	*55*
Mill Capacity growth rate, %	*425*	*0*	*203*
Processing Plant growth rate, %	*41*	*15*	*28*
Plant Capacity growth rate, %	*38*	*12*	*24*
Ice Factory growth rate, %	*53*	*7*	*28*
Factory Capacity growth rate, %	*50*	*5*	*26*

source: Patil & BFDA Database, 1997

One well known example, Waterbase Ltd (TWL) a unit of the Thapur Group, faced severe set backs between 1994-1995. Hatchery and feed sales plummeted due to negligible demand and its processing facilities remained closed for most of the year. The company sold only 62.03 million seed against a projected target of 100 million for the year. This was a result of limited stocking during the year. TWL's feed sales of 6,150.31 tonnes were approximately 45 percent of the projected target for the year. This decline was a result of reduced demand in the market as a result of the truncated period of culture throughout the country and the continual failure of crops. Against a projected shrimp output of 640 metric tonnes the company produced only 56.75 metric tonnes. The company's processing plant operated for only a small portion of the year and processed only 249 metric tonnes against a 1,625 metric tonne capacity. In total TWL incurred a total loss of Rs. 13.35 crores. Of this total amount, operating losses accounted for Rs. 5.34 crores, interest and financing charges accounted for Rs. 5.5 Crore and depreciation accounted for Rs. 2.51 Crore (Reddy, 1996).

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[43] The low growth rate for feed is explained by the fact that 13 of the 14 feed mills were in operation since 1992.

3.4.2 1996 Boom

In sync with the region's most successful culture period (1996-1997) and bumper harvest in October 1996, each ancillary services (with the exception of feed mills) operated at near capacity levels during this year providing a boost to the local economy. Input data collected from an 82 KAA shrimp farm sample suggest that average seed input requirements for marginal, small, medium, large and corporate farms per crop cycle were 15,000; 48,600; 141,820; 381,439; and 6,342,833 pieces respectively. Average feed input requirements for each marginal, small, medium, large and corporate farm per crop cycle were 120; 473; 2,7036; 9,109; and 329,163 kilograms respectively (see Table 3.10).

3.4.3 Summary

It is clear that a flourishing industry of supporting services to the shrimp farming sector has developed in Nellore district over the past decade. The abundance of firms providing necessary inputs enables farms of all sizes the opportunity to purchase inputs at the given price. Competition between firms in each supporting sector ensures competitive prices. Support services, however, are undoubtedly at the mercy of successful harvests. Ice factories and processing units support harvest and post-harvest activities, respectively. Feed mills and seed hatcheries must maintain a minimum standard of quality. With healthy competition between firms, it is imperative that farmers do not equate an unsuccessful season to bad feed or weak seed. Nonetheless, as firms differentiate themselves in terms of brands, etc. a competitive sector of supporting services will undoubtedly thrive. Moreover, the spin-off effects of the growth and development of a new series of firms in an economy are large. In this respect, jobs are created and tax revenues are secured.

Chapter 4

Shrimp Farming & The Impact of Changing Land Use Patterns on Agricultural Labour

4.0 Introduction

There is much debate as to how the growth of shrimp farming in the Kandaleru region has affected the pattern of land use and consequently the structure of the rural labour market. Land previously regarded as agriculturally unproductive by the government and therefore classified as "wasteland" is now put to use for the purpose of shrimp aquaculture. Simultaneously, fertile agricultural land is indiscriminately converted to shrimp farms as traditional paddy, *jowar* and groundnut farmers realise the potential for greater profits by farming shrimp. Similarly, salt pans are being converted to shrimp ponds. Moreover, there is growing concern by local and international NGOs over more frequently reported incidents of ground water salinity, agricultural land salinity and other environmental externalities believed to be caused by shrimp aquaculture development. In addition, the impact of both agricultural and non-agricultural land conversion on the local labour market is of concern. Overall, there are many questions, but few answers with respect to shrimp farming and the impact of changing land use patterns on agricultural labour.

This chapter explores the changing pattern of land use and employment in the Kandaleru region since the advent of shrimp farming. Section 4.1 examines the land purchase and leasing schemes which enabled shrimp entrepreneurs to enter the sector. Section 4.2 examines the magnitude of land conversion for shrimp farming. Section 4.3 examines the evolving pattern of land use at the district, *mandal* and local level. Specifically, this section discusses the degree to which public and private criticism of the shrimp farming sector is justified with respect to employment opportunities gained or lost as a result of it's growth and development. It explores the hypothesis that traditional agriculture and agricultural labour have been displaced since the advent of shrimp farming. Section 4.4 explores the on-farm labour requirements of farms of all sizes.

Specifically, it analyses the degree to which on-farm employment opportunities are available to local inhabitants. Finally, labour requirements needed in traditional agriculture are compared against those needed in shrimp farming.

4.1 Land Purchase & Leasing Schemes

The previous chapter characterised the growth and development of shrimp farms in Nellore district. Survey data suggest that farm ownership status varies by farm size. Eighty-two percent of small farmers surveyed claimed to own their land, while the remaining 18 percent leased land. Similarly, 91 percent of corporate farmers owned their farm land whereas only 9 percent of them leased land. Finally, a more even split was found to exist for medium size farms. Fifty-six percent declared ownership rights to land while 44 percent claimed to lease their land. Although data were not collected regarding the pre-shrimp culture origin of shrimp farmers, many are thought to have come from outside the region. Of interest, therefore are the arrangements used by non-natives to purchase and lease prime shrimp farming land. In fact, non-native farmers had only three ways of accessing land to farm shrimp: private land sales which shifted ownership rights from traditional owners to the purchaser; private lease arrangements which enabled the lease of land under specific conditions; and government leasing and transfer schemes, which allocated public land for the purpose of farming shrimp. In this section, each arrangement is discussed in turn.

4.1.1 Private Sale of Land

The rental price for privately owned land located adjacent to the Kandaleru river rose steeply over ten years between 1987 and 1997.[1] Prior to 1987 privately owned and government public access land adjacent to the

Kandaleru was left barren and uncultivated. Before the advent of shrimp farming, this land was unpopular for essentially three reasons. First, it was unsuitable for most agricultural crops. Besides being used for small scale charcoal making and cultivation of small scale seasonal cash crops such as Coriander, this land was generally considered unproductive by local owners.[2] Second, land adjacent to the Kandaleru creek serves as a perennial drain for the monsoon flood waters (Land Records Office, 1997). Historically, during particularly heavy monsoons, the creek overflows its banks and causes flash flooding.[3] Therefore, very few inland villages are found closer than a few kilometres away from the river. Third, the variable salinity of the creek as far up as 40 kilometers upstream from the Bay of Bengal make it useless as a source of portable water. In addition, most communities along the upper stretches of the Kandaleru are primarily engaged in agricultural activities and find little use for the brackishwater creek.

Records obtained from the district's Land Records Office (LRO) in Gudur indicate that prior to 1987 very few private transactions occurred with respect to land adjacent to the Kandaleru river. With the introduction of brackishwater shrimp aquaculture to the region in 1987, demand for this wasteland began to rise steeply. Initially, this land commanded an average price of approximately Rs. 2,469 per hectare.[4] With recognition of shrimp farming's commercial possibilities, land prices jumped to Rs. 86,415 per hectare in 1991. By 1993, the same land commanded an average per hectare sale price of Rs.

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[1] Privately owned land is regionally referred to as *Patta* land. These two terms are used interchangeably throughout this section.

[2] Informal discussions with local inhabitants suggest that government classified "wasteland" does have productive capacity. Previous to shrimp farming, the thorny bushes growing on the "wasteland" were used to produce charcoal. In addition crops requiring very few nutrients from the soil were grown and sold in the local market. Charcoal making and secondary dryland crops were farmed usually by landless labourers who gained permission of the owner or encroached on government owned land. It is unclear, however, how many poor local inhabitants are currently restricted from this income generating activity. It is unclear as to the value of this loss of economic activity.

[3] The most recent flash flooding occurred in 1995. Entire shrimp farms were washed away and the entire Kandaleru region was under water for several weeks.

[4] All land purchase prices were provided by Land Records Office in Indian Rupees per acre. Lease prices were obtained from interviewing land lords and leasees. All land prices are converted to per hectare prices in order to provide some degree of consistency throughout the

92,587 for land located at a distance from Kandaleru creek but connected to it by a feeder canal, and Rs. 123,440 for each hectare of land located directly adjacent to the creek. By October 1996, per hectare land prices were in excess of 197,520 Indian Rupees. This suggests an annual average land price inflation of 73 percent since 1989.[5]

In 1997 and 1998 land prices have remained high, but demand has slumped due to the uncertainty faced by the industry as a result of the December 1996 Supreme Court order banning shrimp farming (see Table 4.0).[6] Whereas annual average price inflation was in excess of 88 percent before the shrimp virus outbreak in 1994, average annual inflation was a modest 21 percent over the post-disease years, 1995 to 1997. Shrimp farming is undoubtedly responsible for the sharp rise in land rents in coastal Nellore.[7]

Table 4.0

Private per hectare Land Purchase & Lease Prices (1989-1997)

Year	*Average Purchase Price (Rs/Hectare)*	*Average Private Lease Price (Rs/Hectare/Year)**
1989	2,469	no recorded transactions
1990	12,345	no recorded transactions
1991	86,415	no recorded transactions
1992	92,587	no recorded transactions
1993	92,587	14,814
1994	111,105	17,283
1995	123,440	19,752
1996	197,520	44,442
1997	no recorded transactions	no recorded transactions

sources: Gudur Land Records Office, 1997; *Based on personal interviews of land lords & renters; prices are nominal and not adjusted for inflation.

4.1.2 Private Lease Arrangements

In late 1993 there was a shift from outright sale of wasteland recognised to be suitable for shrimp cultivation to leasing arrangements. Land owners saw

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thesis. For comparison purposes only, prime agricultural wet land commanded an average renal price of 4,722 Rupees per hectare in Andhra Pradesh between 1980-1990 and at 1980 prices.

[5] Similar events have been observed in Tamil Nadu where coastal land prices shot up from Rs. 17,500 a hectare in 1992 to over Rs. 200,000 per hectare in 1994 as a result of high demand for prime shrimp farming land (Viswanathan, 1994:78). This amounts to an average annual growth rate of 124 percent between 1992 and the end of the 1994 season.

[6] Personal communication with the President of the KAA, March 1998.

opportunities to capture economic rent while maintaining ownership rights. A significant proportion of smaller land owners interviewed, claimed that they did not have either the means or the desire to develop shrimp ponds themselves, and therefore opted to lease their land instead. This group includes small paddy, jowar, casuarian and groundnut farmers with land ownership rights through bequests.[8] Based on semi-structured interviews of land owners and renters, land for shrimp cultivation commanded an average annual per hectare lease price of approximately Rs. 14,814 in 1993, Rs. 17,283 in 1994, Rs. 19,752 in 1995 and Rs. 44,442 in December 1996.[9] This suggests an inflation adjusted average annual growth rate of approximately 25.6 percent.

In the 1994-1995 culture season there was an even greater shift from direct purchases to leasing arrangements. During this season, average shrimp yields dropped by 60 percent from the previous year due to a region wide shrimp disease outbreak.[10] The impact of 1994 disease and 1995 flood on land lease schemes was two-fold. First, larger land owners saw (perhaps for the first time) the significant risk involved in farming shrimp. Those owning land adjacent to the Kandaleru and who previously had plans to enter the industry shied away from it instead. Despite decreased demand for land by local inhabitants of the Kandaleru region, demand for land by outsiders most likely rose and rental prices continued to rise. The Kandaleru regions' 1996-1997 bumper shrimp harvest helped drive up the price of land significantly. Yearly lease prices per hectare also jumped 44 percent from Rs. 19,752 to Rs. 44,442 (see Table 4.0).

Overall, the lease price per hectare as a proportion of the sale price per hectare was relatively constant at approximately 16 percent between 1993 and 1995.[11] This was a steady ten percent above average annual inflation for the period. However, in 1996, the lease/sale price ratio per hectare rose by 6.5

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[7] The discussion of land transactions and contracts is based on semi-structured interviews of land lords, their clients and government officials of the land records office, Gudur. Transaction prices are supplied by the same.

[8] See Center for Development Studies (1991) for a good discussion of A.P. village land bequests.

[9] This was before the Indian Supreme Court verdict announced December 15, 1996 banning shrimp farming in the country.

[10] see Chapter 3, Section 3.2.1.

[11] This is calculated by taking the ratio of the per hectare lease price to the per hectare sale price for each year between 1993 and 1996 (see Table 4.0).

percent to 22.5 percent, on average. This suggests that land lords took advantage of the fact that demand for land purchase fell, while demand for rental property rose. At the same time, the willingness of land owners to sell their land declined. Both factors are likely to have contributed to the jump in the land lease price.

Land Lease Contracts

Contracts for private land lease vary slightly across the different shrimp farming clusters of the Kandaleru region. Lease periods were fixed for a minimum of two years and maximum of four years after which the contract could be re-negotiated. In almost all cases rental contracts were adjusted for inflation.[12] In several cases, the current owner of wasteland was not the historical owner, but an individual who purchased large tracts of land from the family or clan with historical ownership rights. Land was usually purchased as an investment by those with intentions of farming shrimp.[13] However, several property owners revealed that as a result of generating a steady income from rent, they did not engage in shrimp farming themselves. Other land owners leased a proportion of their land to other shrimp farmers and also chose to culture shrimp themselves.

Both purchase and lease prices vary according to the property's distance from the creek. Land prices fall as the property's distance from the creek increases. This may be a function of a farmer assuming greater risk when farming on land further away from the brackishwater source. Shrimp farmers operating on land adjacent to the brackishwater source have a greater control over water intake and effluent discharge and therefore greater control over risk. Shrimp farms located further away from the brackish water source rely on *shared canals* for water intake and effluent discharge. Interviews of shrimp farmers suggest that there is a greater risk of pond contamination when the intake waters are shared via a common canal. As the chance of contaminated intake water increases, the greater is the possibility of crop disease and economic losses faced

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[12] The constant per hectare land sale/lease price ratio bewteen 1993 and 1996 suggest this to be the case.

[13] This is not unlike arrangements in Bangladesh witnessed by Guimaraes (1989).

by shrimp farmers. However, as there is only a finite amount of land located directly adjacent to the water body, most farmers share common canals, and therefore assume this risk.

4.1.3 Government Schemes

In March 1991, *Government Order MS.199(Fish II)* officially set up the government land allotment, subsidy and leasing scheme in Andhra Pradesh. In 1991, government owned land was allotted to aquaculture entrepreneurs according to the following annual per hectare guidelines: (1) fishermen co-operatives were eligible for up to a maximum of 2 hectares per member at Rs. 10; (2) self-employed technocrats were eligible for up to 4 hectares at Rs. 20; (3) progressive entrepreneurs and both privately and publicly financed companies were eligible for up to 40 hectares at Rs. 50.[14] By 1993, however, the annual government lease arrangements were revised to reflect the success of government initiatives promoting shrimp farming and to generate greater government income. The new arrangements were revised as a result of strong profits realised by shrimp farmers. As of December 1996, the new per hectare annual rates were as follows: (1) fishermen co-operative quotas were reduced to 1 hectare per family at Rs. 500; (2) self-employed technocrats were eligible for up to 10 hectares at Rs. 5,000; (3) private and public corporations were eligible for up to 100 hectares at a minimum of Rs. 5,000.

As of November 1994, the government land allotment and subsidy scheme had benefited a minority 164 shrimp farmers for a total of 2,359 hectares of government land in Andhra Pradesh. In Nellore district alone, 153.5 hectares had been allotted to fishermen co-operatives; 172 hectares to technocrats and 640 hectares to corporate entrepreneurs or 965.5 hectares in total (Rastogi, 1995). This amounted to 41 percent of the total land area allotted in Andhra Pradesh. In this respect, Nellore was by far, the most well endowed district in the state.

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[14] Progressive entrepreneurs are defined as those farmers who would bring “scientific” farming methods to the region by the BFDA.

4.2 Land Conversion & Shrimp Farming

There is much debate over the impact of changing land use patterns on agricultural labour. Aquaculture Associations and organisations supporting the industry claim that mostly government classified wasteland is converted. They argue that wasteland is often left barren and is essentially unproductive for agriculture. Moreover, they argue that no labour is displaced since uncultivated land is primarily converted to shrimp farms. In contrast, NGOs claim that it is not wasteland, but agricultural land that is most often converted to shrimp ponds. They point out, and perhaps correctly, that once converted to shrimp ponds, former agricultural lands (even if converted back to agriculture) cease to be productive for agricultural crops as a result of high salinity. However, the literature is devoid of any rigorous attempt to discover the extent of land conversion, yet alone its implications. The next two sections attempt to do so by drawing on previously unpublished government data collected from government agencies located in Nellore city.

4.2.1 Extent of Land Conversion

Analysis of the Chief Planning Office's (CPO) Agricultural Census data suggest that between 1991 and 1995, a combination of barren and uncultivable wasteland, agricultural land and pasture lands may have been converted to shrimp farms. Previous to 1991, the amount of barren and uncultivable wasteland in Nellore remained essentially constant at 60,122 hectares. The 1995 census figure suggests that there was a drop of 2,063 hectares of wasteland or 3.43 percent since 1991. Total agricultural land area fell 3.52 percent over the period and total pasture land area fell 13.51 percent. According to this census data, shrimp farms occupied approximately 2,745 hectares of district land in 1995 or 2.08 percent of the district's total land area.[15] However, it is speculative

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[15] Kandaleru farms alone occupied 2,166 hectares of land in 1997 (Patil & KAA Database, 1997).

as to the proportion of wasteland, agricultural land, and pasture land converted to shrimp farms. More location-specific data is needed to accomplish this task.

Table 4.1 presents official statistics collected by the District Collector's Office (DCO). The DCO survey identifies the number of shrimp farms in Nellore district by *mandal,* the amount of private agricultural dry-land and wetland, government owned land, forest area and salt pans converted to shrimp farms between 1990 and 1996. However, based on the total area under shrimp culture of just the 518 KAA farms and other official government statistics, it is clear that the DCO statistics reported below are most likely underestimates.[16] Nonetheless, these data give some indication of the trend and magnitude of land conversion in the district prior to 1996.

As per the records of the local DCO, 2,835 hectares of agricultural land and 65.7 hectares of salt pans have been converted to brackishwater shrimp ponds since 1990 (DCO, 1996). Of the 2,835 hectares of converted agricultural land, 74 percent (2,099.5 hectares) was contributed by *dry-land* where agriculture requires far less labour inputs (Acharya, 1992:170) and is allegedly less profitable (Krishnan *et al.*, 1996). The conversion of 735 hectares of fertile agricultural *wetland* or 26 percent of all agricultural land converted is of some concern as this land has significant productive capacity. As a percentage of the total amount of land area in Nellore district, agricultural wet-land conversion is minimal at 0.2 percent. In order to protect India's fertile agricultural land from conversion to shrimp ponds and as a result of mounting pressure from environmental NGOs, the Indian Supreme Court in 1994 passed a law to make this practice illegal.[17]

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[16] According to AD Fisheries and BFDA data, as of 1995 approximately 5,424 hectares of land are under shrimp farming. A total of 3,755 hectares of agricultural and government lands were converted. This leaves 1,669 hectares unaccounted for. We suggest that much of this unaccounted land is most likely government classified wasteland.

[17] Ministry of Forestry & Fisheries Order XIV; April 1994.

Table 4.1
Extent of Land Converted (by type) to Shrimp Farms (Hectares)

Mandal	# Shrimp Farms*	Agricultural & *Patta* Lands Converted		Government Lands Converted			Forest Land	Salt Pans	Total Land Converted
		Wetland	Dryland	Unauthorised	Authorised	Total			
Kavali	78	0	163.7	16.5	12.2	27.8	0	0	192.4
Bogulu	26	177.0	159.3	0	0	0	0	0	336.3
Allur	71	0	496.3	68.7	29.5	98.2	0	53.2	647.7
Vidavalur	66	22.7	16.6	0	0	0	0	12.6	51.8
Idukurapet	356	179.3	126.4	27.7	19.1	46.8	0	0	352.5
TP Gudur	22	0	365.8	0	6.1	6.1	0	0	371.9
Muthukur	276	27.1	175.3	71.2	0	71.2	0	0	273.6
Chillakur	189	3.1	0	73.8	3.2	77.0	0	0	80.1
Venkatach.	51	22.1	164.4	11.5	7.9	19.3	0	0	205.9
Manubolu	13	0	24.2	0	1.3	1.3	0	0	25.6
Kota	32	8.4	39.0	230.6	0	230.6	0	0	278.0
Chittamur	25	71.8	22.4	16.5	6.6	23.1	0	0	117.4
Vakadu	46	234.3	324.5	241.1	0	241.1	0	0	800.0
Tada	7	0	22.2	0	0	0	0	0	22.2
TOTAL	*1,258*	*745.8*	*2100.2*	*757.6*	*85.9*	*843.5*	*0*	*65.7*	*3,755.3*

source: 1996 District Collector Revenue Records, Nellore; *AD Fisheries, Nellore

By 1995, 844 hectares of government owned land had been converted to shrimp farms.[18] However, almost 90 percent of it was unauthorised. This means that coastal land was encroached upon by entrepreneurs interested in cultivating shrimp. The type of land included in government owned land include wasteland, public access land, and pasture land. While almost 86 hectares of government owned wasteland was authorised for conversion, it is unclear as to how much of the unauthorised 844 hectares of government owned land was classified as wasteland. It is likely that a majority of the unauthorised government owned land came from public access, public pasture land and not agricultural land. This is simply because the government owns very little agricultural land along the coast.

Finally, the available data do not reveal the total amount of non-agricultural private land converted to shrimp farms. This is hypothesised as making up the bulk of the land conversions taking place in the district.[19]

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[18] According to Rastogi (1996), 965 hectares of government owned wasteland was authorised for conversion in Nellore district by 1996. See section 4.1.3 for greater detail and discussion.

[19] This hypothesis is offered based on the changing pattern of land use along the Kandaleru observed during field research. In addition, topographical maps made available by the LRO indicate that land located next to the Kandaleru river is classified as either wasteland (i.e. barren and uncultivable) or pasture land. Very little land located adjacent to any of the district's brackishwater rivers appear to be agricultural land. Global Information Systems (GIS) data, however may prove otherwise. Indian GIS data, however is classified. Repeated attempts to

However, in absence of more refined and reliable data, it is not possible to explore this any further.

The DCO data while providing a detailed breakdown on the amount of productive lands converted in Nellore district does not in itself reveal whether a rural crisis exists as a result of conversion. Economic theory suggests that rational agents will convert agricultural land when the expected returns of shrimp farming outweigh the current returns of farming agricultural produce. In itself, conversion may not be a serious problem as long as farmers fully engaged in agriculture fill any slack in agricultural output as a result of those exiting agriculture and entering shrimp farming. However, in a poor country like India, converting prime agricultural land is tragic. Leaving aside the possible environmental consequences of a massive shift to shrimp farming, activists claim that the conversion of both agricultural and non-agricultural lands to shrimp farms will reduce employment opportunities for local populations.[20] In the next section, the hypothesis, that traditional agriculture and agricultural labour have been displaced since the advent of shrimp farming, is examined with respect to district, mandal and local level data.

4.3 Land Use & Employment in Nellore

It is well known that a shift in land use patterns could involve a change in direct and indirect employment opportunities (Pal, 1995). Several studies conducted by Indian NGOs have alleged that shifts from primary agricultural activities to shrimp farming reduce the output of primary crops such as rice, ragi and salt and ultimately adversely affect poor rural populations through job loss and even starvation (PREPARE, 1996).[21] The Indian Supreme Court agrees to some degree (Supreme Court Notification, 1996:20). This research, however,

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attain satellite topographical imagery from the National Remote Sensing Agency was denied for this reason.

[20] A review of the available literature is presented and discussed in Chapter One.

[21] These studies are simulations and not case studies based on field data.

scrutinises this claim. Although many authors have argued that both direct and indirect local labour would be displaced from the agricultural sector if shrimp cultivation replaced primary crop production, no empirical study to date has rigorously addressed this assertion for India.

Direct employment levels in agriculture can be measured by the number of cultivators (owner cultivators and tenant farmers) operating in the district. Indirect employment can be measured by the amount of additional labour hired by owner cultivators. Overall, direct and indirect employment and output yields would be affected if the district-wide number of cultivators and net sown area declined over the period (1991-1996). Generally, a decline in the net sown area would indicate that fewer labourers were needed for on-farm agricultural activities. If this were found to be true, the results could support two plausible conclusions: (i) that local agriculture became increasingly capital intensive over the period and thus displaced labour, or (ii) to some extent, shrimp farming (in conjunction with other recently introduced activities, or alone) is actually displacing traditional agricultural land and labour. This research seeks a reasonable answer to the question whether coastal communities are indeed facing a significant exodus away from agricultural production to shrimp culture as NGOs fear. Moreover, this research examine whether there is any evidence of significant declines in agricultural land use and on-farm employment between 1990 and 1995.[22]

4.3.1 Analysis of District Level Data

Examination of the CPO's Agricultural Census data (1990-1995) reveals that the overall negative impacts on employment of agriculture land conversion to ponds is perhaps overstated in the literature. Table 4.2 presents the total number of cultivators and the area they cultivated from 1991 to 1995 in Nellore district. These data suggest that since 1990 the overall net sown area for Nellore district has remained relatively constant over the period. Overall, the net sown

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[22] These two indices are strictly comparable as the net sown area was almost identical in 1990 as to that area sown in 1995 (see Table 4.2).

area in 1995-1996 is marginally lower than in 1993-1994 which is the maximum for the period under consideration. Any fluctuation over the period follows the current and other fallow trend suggesting no deviation from historical cropping patterns over the five years.[23] In fact, the number of owner-cultivators and tenant farmers increased by 5,503 over the period. This is most likely due to division of private family owned land through bequests. This well known pattern in Andhra Pradesh is documented in case studies presented in the Indian Journal of Agriculture (1996) and in an in depth analysis of several agricultural communities reported in CDS (1993).

An index of total cultivators operating per hectare of sown area (see Table 4.2) suggests that the number of workers per cultivated hectare has shown an overall net increase from 0.425 to 0.445 between 1990 and 1995. This increasing trend suggests that more primary labour inputs are utilised for the same unit area of cultivated land in the district. Overall, at the district level, the CPO data suggest that during its boom, shrimp aquaculture development has had little impact on agricultural land and labour use at a district level of analysis. But, does the same relationship hold true for those *mandals* most intensively involved in shrimp farming? This is explored next.

Table 4.2

Net Sown Area (HA) & Total Number of Cultivators in Nellore (1990-1995)

District Wide Analysis	*1990-1991*	*1991-1992*	*1992-1993*	*1993-1994*	*1994-1995*
TOTAL CULTIVATORS	48,421	54,448	54,617	54,617	50,650
NET SOWN AREA (HA)	113,845.5	115,026.5	116,184.8	112,171.6	113,851.6
***INDEX**	0.425	0.473	0.470	0.487	0.445

source: CPO (1996); Author's calculations
*Total cultivators per net sown hectare of agricultural land; the index is essentially normalised by land since the net sown area was essentially constant between 1990-1991 and 1994-1995 seasons.

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[23] The net sown area, current and other fallow land variables in the CPO time series are negatively correlated for each year but not significant. This is supported by the historical relationship between area sown and fallow area in any given year which follows the same pattern (see Acharya, 1992).

4.3.2 Analysis of Mandal Level Data

CPO data suggest that shrimp farms occupy approximately 2.08 percent of the total land area in Nellore district. However, the proportion of total land area occupied by shrimp farms significantly varies by *mandal.* Indukurpet is by far, the district's largest shrimp farming mandal. According to BFDA estimates, Indukurpet shrimp farms occupy 1,326 hectares of land, amounting to 7.3 percent of that mandal's total land area. It is also the mandal most intensively farming shrimp since it is the mandal with the highest proportion of total land area engaged in shrimp cultivation. Basic statistical tests suggest that mandals more intensively farming shrimp (i.e. those mandals with a higher percent of the total area under shrimp culture) have positive and significant correlation with the total area under shrimp culture.[24] The question remains, are the mandals most intensively farming shrimp likely to be equated with low labour use per net sown area? This research suggests not.

An index of total cultivators operating per hectare of sown area for each mandal between 1990 and 1995 is presented in Table 4.3. The district wide analysis described earlier reveals that the number of workers per cultivated hectare has shown an overall net increase over the period. Next, it is possible to examine whether a similar pattern exists at the mandal level. All Nellore district mandals engaged in shrimp farming are divided into two categories, those most intensively farming shrimp (i.e. those six mandals with shrimp farms occupying greater than 2.0 percent of the available land area) and mandals least intensively farming shrimp (i.e. those six mandals with shrimp farms occupying less than 2.0 percent of the available land area) and compared.

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[24] The correlation coefficient is 0.97 and significantly different from zero at the five percent level.

Table 4.3
Area Under Shrimp Farming in Nellore District Mandals (1995)

Mandals	Area Under Shrimp Culture (HA)	% of total land area under shrimp culture
mandals most intensively engaged in shrimp farming		
Kavali	NC	NC
Bogolu	332.1	2.02
Allur	632.2	3.21
Vidavalur	503.8	3.18
Indukurpet	1,326.4	7.30
T.P.Gudur	794.6	4.33
Muthukur	450.4	2.62
mandals least intensively engaged in shrimp farming		
Venkatachalam	152.3	0.52
Manubolu	135.7	0.56
Chillakur	547.6	1.65
Kota	47.0	0.25
Vakadu	396.1	1.78
Chittamur	106.5	0.38
D.V.Satram	NC	NC
Tada	NC	NC

Patil & BFDA Database, 1996; NC means not calculated due to a lack of data

Three of the six most intensive shrimp farming mandals, Bogolu, Allur and Indukurpet mandals show an average index decline of 0.072 between 1990 and 1995 (see Table 4.4). The indices of the three remaining intensive shrimp farming mandals rose an average of 0.092 over the same period. Overall, the relationship between the overall change in the index and the percentage of land area in each of these six mandals was not found to be significantly different from zero at the ten percent level.[25] An almost identical pattern is found for the six least land intensive shrimp farming mandals in the district.[26] In fact, taking the top four most land intensive mandals under shrimp farming, the relationship between the percentage area under culture and labour use intensity index is slightly positive and significant.[27] Therefore, based on mandal level data, it is

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[25] The correlation coefficient is r= 0.086 with p= 0.86

[26] The correlation coefficient is r= 0.085 with p= 0.87

[27] The correlation coefficient is r= 0.04;with p= 0.95

possible to conclude that the amount of agricultural land and labour being displaced by shrimp farming is not significantly different from zero. In fact, the data supports the finding that in the most intensive shrimp farming mandals, the labour use per net sown area between 1990 and 1995 has actually significantly increased.

Table 4.4
Labour Use Intensity Index*

mandal	*1990-1991*	*1991-1992*	*1992-1993*	*1993-1994*	*1994-1995*	change
Kavali	0.397	0.487	0.465	0.510	0.500	0.103
Bogolu	0.559	0.502	0.481	0.523	0.547	-0.013
Allur	0.665	0.447	0.358	0.481	0.480	-0.185
Vidavalur	0.322	0.357	0.459	0.461	0.410	0.088
Indukurpet	0.478	0.448	0.423	0.459	0.459	-0.019
T.P.Gudur	0.282	0.418	0.539	0.431	0.460	0.179
Muthukur	0.444	0.543	0.603	0.529	0.453	0.009
Venkatachalam	0.473	0.600	0.420	0.599	0.649	0.176
Manubolu	0.126	0.433	0.531	0.426	0.418	0.292
Chillakur	0.321	0.593	0.497	0.540	0.687	0.366
Kota	0.479	0.517	0.390	0.487	0.456	-0.023
Vekadu	0.586	0.405	0.504	0.451	0.410	-0.175
Chittamur	0.486	0.456	0.424	0.446	0.340	-0.146
D.V.Satram	0.529	0.448	0.525	0.442	0.449	-0.080
Tada	0.347	0.531	0.525	0.508	0.509	0.163

*total cultivators per net sown hectare of agricultural land
source: BFDA Data, 1996

4.4 On-Farm Employment

There is a large empirical literature on the Indian rural labour market. It is characterised by the prevalence of personal ties between employers and employees and distinctive in its characteristics between permanent (regular) and temporary (casual) employment, duration of both types of employment and with respect to wage and non-wage benefits (Rudra, 1982; Bardhan, 1984; Binswanger & Rosenzweig, 1984; Reddy, 1985; Dreze & Mukherjee, 1987). These relationships, however, are entirely based on agricultural studies. Much less is known, yet alone documented regarding the labour requirements, characteristics and contracts of shrimp farms. This section discusses each of these in turn with respect to primary farm level survey data collected from a sample of 82 Kandaleru shrimp farmers. Specifically, the hypothesis that fewer labour inputs are required in cultivating one sown hectare of rice as opposed to culturing one water spread hectare of shrimp is examined.

The structure of this investigation of on-farm employment in the aquaculture sector is as follows: Section 4.4.1 presents some stylised facts characterising the traditional seasonal rural labour market in India. These characteristics are compared with lesser known employment patterns in the emerging shrimp farming sector. Section 4.4.2 presents an overview of the production cycle in shrimp farming. This includes the pond preparation phase, culture period, and harvest season. The duration of each phase is examined. Section 4.4.3 examines the characteristics of labour use in the production cycle. It illustrates that each phase in the production cycle requires a different mix of labour inputs and labour requirements also vary by farm size and culture intensity. Section 4.4.4. briefly discusses female-male participation rates for each phase of the production cycle. Section 4.4.5 surveys the labour requirements of shrimp farms. Specifically, the use of temporary labour inputs are distinguished from the amount of permanent labour hired. Similarly, a distinction is made between hired and family labour employed. Finally, section 4.4.6 compares the amount of unskilled labour employed in six primary agricultural crops with the estimated labour requirements of shrimp aquaculture.

4.4.1 Characterising the Indian Rural Labour Market

According to the vast literature comprised of case studies, large Indian agricultural farms hire permanent workers for the duration of the production year, especially in paddy and cotton cultivation. They tend to be involved in activities such as soil preparation, fertilisation and irrigation (Agarwal, 1981; Reddy, 1995). Casual or temporary workers are usually hired for activities such as transplanting, weeding and harvesting (Reddy, 1995). In addition, temporary casual workers tend to work for fewer hours per day than permanent workers and are rarely asked to perform non-agricultural tasks, unlike permanent workers. The daily wage for permanent workers is usually less than the daily casual workers' wage. However, due to the nature of each contract, the annual permanent workers' wage may be higher than the annual wage of a casual worker (Sanghvi, 1969; Ghose, 1980; Basant, 1984).

The seasonal nature of agricultural production plays an important role in the choice of rural labour contracts. Several studies find that employers offer some regular labour contracts at the beginning of the agricultural year in order to ensure a ready supply of labour at the needed times. In addition, recruitment costs are reduced and wage fluctuations are minimised over the slack and peak periods (Bardhan, 1984; Eswaran & Kotwal, 1985a; Guha, 1989; Dasgupta, 1993). Similar contracts are thought to be made in the shrimp farming sector too.

Based on the vast literature characterising rural labour contracts, Pal (1995:4) suggests three stylised facts. First, agricultural labour can be characterised by the *seasonal nature of production and employment.* Given the seasonal fluctuations of agricultural production over the peak and slack periods (Bardhan, 1984; Mukherjee, 1991), labour demand is low in the slack season so that seasonal idleness of regular labour is an important consideration for farms (Guha, 1989). Second, given a high degree of inequality in the distribution of land and non-land resources, only a few farms are large while a majority of the farms are small or medium. Usually larger farms hire permanent workers while smaller farms primarily rely on casual labourers (Basant, 1984; Walker & Ryan, 1990). Thus there is some degree of *heterogeneity of farms.* Third, the daily wage bill of permanent workers is lower than that of temporary workers (Sanghvi, 1969; Ghose, 1980; Basant, 1984). However, permanent labour also receives non-wage benefits such as access to credit, homestead land and bonuses (Binswanger et. al., 1984; Alexander, 1973). Therefore, there exist *permanent-temporary wage and non-wage differentials.*

Little is known about the employment patterns in shrimp farming. Against the backdrop of the stylised facts for agriculture, the on-farm labour requirements of shrimp farming are examined. The empirical investigation begins with an examination of labour use over the shrimp farm production cycle. Throughout this analysis, labour use is categorised primarily by the size of land holding as opposed to the culture technology adopted. This is a result of earlier analysis which suggests that the correlation coefficient between farm size and stocking density (a proxy for capital intensive technology) is strongly positive and significant.

4.4.2 The Production Cycle

There are three important phases in the shrimp production cycle, namely, pond preparation, the culture period and pond harvest period. In the pond preparation phase (phase 1), bunds are repaired, the pond floor is weeded and cleaned and brackish water is pumped into the pond. In the culture period (phase 2), each pond is stocked with seed and the daily feeding process begins until the shrimp fry grow to maturity.[28] In the harvest period (phase 3), ponds are drained and the shrimp are either scooped into nets or picked up off the pond floor and placed directly into baskets of flaked ice. The baskets are loaded onto refrigerated trucks which transport the harvest to peeling sheds for packaging, freezing and export. The pond preparation phase, culture period and harvesting period in shrimp farming is not dissimilar to the soil preparation, growing period, and harvesting season corresponding to agriculture.

In the Kandaleru region, the culture cycle occurs between two to three times each year. The number of annual crops depends on a mix of geographic factors and the type of production technology adopted. For example, more capital intensive shrimp farms tend to produce three crops per year while less capital intensive farms may culture twice (Patil & KAA Database, 1997b). Farm location can also restrict the number of annual crops cultured since shrimp farms depend on relatively constant water salinity concentrations. Fluctuations in water salinity are often fatal to the crop. Sea-based shrimp farms have steady access to a water supply with a relatively constant salt concentration. On the other hand, inland creek-based farms are more susceptible to fluctuations in the salt content of the creek as a result of seasonal tidal fluctuations. Location along the creek is therefore important.

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[28] Seed in shrimp farming refers to shrimp fry; the harvest weight of mature shrimp is approximately thirty-five grams.

Farms located further upstream (further from the sea) are also found to culture fewer times per year than their downstream counterparts. In fact, a clear majority of creek-based farms operating further than twenty kilometres from the Bay of Bengal operate on a two crop per year cycle.[29] In these areas, the first production cycle begins in mid-January and ends in early June. The second production cycle begins in July and ends prior to the annual monsoon in November.

Duration of Production Phases

The reported duration of each phase in the production cycle also varies with farm size and production intensity. Overall, mean duration of each production phase increases with farm size.[30] Both duration and farm size are significantly and positively correlated with the number of ponds per farm with the exception of duration of phase 2 and farm size which is not significant. This suggests that on average larger farms require a greater number of days for pond preparation and harvest activities, despite greater per hectare labour inputs employed.

However, the reported duration of the culture phase increases with farm size and total number of ponds only because at most, two ponds are harvested daily in larger farms.[31] Although ponds are ready to be harvested, they must continue to be maintained as required by the culture process until management decides to harvest them. This translates into a longer reported culture duration for larger farms. To obtain a more accurate estimate of the mean duration of the culture phase in isolation, the number of days required for the harvest period is subtracted from the number of days required for the culture period. The revised mean duration of each of the three phases is presented in Table 4.5 below.

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[29] Patil & KAA Database,1997

[30] Patil & KAA Database, 1997

[31] Results are based on data provided by 38 large and corporate shrimp farms surveyed in the 82 farm sample.

Table 4.5
Duration of Shrimp Production Phases (in days)

	PHASE 1 *Pond Preparation Phase*				*PHASE 2* *Culture Period*				*PHASE 3* *Harvest Period*			
Size, S *(WSA)*	*Mean, SD, Min, Max*				*Mean, SD, Min, Max*				*Mean, SD, Min, Max*			
marginal $S<1$	7	0	7	7	127.5	17.7	105	130	1.5	0.71	1	2
small $1\leq S<2$	7	0	7	7	127.2	10	110	140	3.1	0.78	2	4
medium $2\leq S<5$	7	0.2	6.5	7.5	121.0	12.4	105	150	5.1	1.9	2	10
large $5\leq S<10$	7.1	0.4	6	8	118.2	19.8	90	185	7.7	1.8	5	11
corporate $10\leq S$	8.1	1.1	7	9.9	107.1	26.7	90	165	16.9	8.8	6.7	32

source: Patil & KAA Database, 1997b

The duration in days of the preparation and harvest phases is therefore positive and significantly correlated with farm size and technology at the one percent level. The mean revised duration of the culture phase is now negatively correlated with both farm size and technology and significant at the five percent level. These results yield more accurate approximations and correspond to the conventional wisdom of the sector.[32]

4.4.3 Characteristics of Labour Use in the Production Cycle

Each phase in the production cycle requires labour to engage in different tasks. The pond preparation phase can require both manual and machine labour. The culture phase can require manual, semi-skilled, and skilled labour. However, this depends on the productive intensity employed by the farmer. The harvest period requires manual and semi-skilled labour. The characteristics of labour use in each phase of the production cycle are discussed next.

The pond preparation phase, requires manual labour inputs and begins after each season's monsoon. The bi-annual monsoon season washes away bunds and reduces the effectiveness of shared canals. Farms require unskilled

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[32] The conventional wisdom in the shrimp farming sector is based on findings from the 1995 Asian Productivity Organisation conference on shrimp culture and the more recent FAO/World Bank technical meeting which brought experts from all over the world to discuss issues facing Asian shrimp farming.

manual labour for general earthworks and bund preparation during this phase which begins after the last rains. First, the pond is left to naturally dry out in the sun. Next, it is cleaned of any residue from the previous culture period. This means that any unconsumed feed that settled to the pond bottom during the previous culture period is removed. Bunds are repaired and drainage canals are strengthened. In larger farms, tractor time is often hired to mechanically prepare the ponds for culture.[33] In the smallest farms, only manual labour is employed. Finally, the sluice gates are opened and water is allowed to fill the pond. After one day under observation, the pond is ready for shrimp culture.

The culture phase requires a mix of both skilled and unskilled labour. In larger farms, skilled technicians such as biologists, chemists and lab technicians are employed to test pond water quality and to ensure a clean aquatic environment with minimal bacterial infections. The bulk of the unskilled labour inputs required are feed boys responsible for feeding the shrimp three to eight times a day.[34] A few unskilled workers from the pond preparation phase are retained for additional earthworks. Semi-skilled guards are hired to protect the crop from bird and human intrusion. Usually they are hired from outside the local community.[35] However, only one third of those employed on farms greater than five hectares in size are hired from the local labour force.[36] Farms over 5 hectares tend to be public or private limited companies run by entrepreneurs from outside the local region. They tend to contract work for different phases from the pre-existing company work force. Small and marginal owner-operated farms tend to use own and family labour for many of these tasks. These farmers do not tend to employ capital intensive culture practices. Outside of feeding the crop several times daily and guarding, there is not much physical labour required. Medium size farms tend to hire local workers on an annual contract basis.[37]

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[33] Large and medium size farms always use hired tractor labour. Owners of small size farms adjacent to each other will often band together and contract tractor time.

[34] This is consistent with feeding practices in other shrimp farming districts in India (see APO, 1995).

[35] This became clear as a result of informal discussions with farm hands.

[36] Based on discussions with managers of large and corporate farms and farm hands.

[37] This is discussed in detail in Section 4.4.5.

The harvest period requires mostly semi-skilled labour to drain each pond, capture and collect the shrimp, and pack the harvest in ice. This research finds that small and marginal farmers rely on household labour for additional hands. Larger farms hire temporary workers to engage in harvest activities.[38]

4.4.4 Gender

Quite a lot is known about the gender composition of labour used in intensive shrimp farming and ancillary services as a result of three key studies. In a study of eight intensive shrimp farms, Hoon (1995) concludes that employment opportunities throughout the production cycle disproportionately favour men. This is a result of (i) corporate farms contracting labour from outside the region, and (ii) requiring labour to live on the farm for the duration of the season. Similar observations are made with respect to intensive Kandaleru farm labour. In contrast, studies conducted by Banerjee (1992), Baud (1992) and Hoon (1995) report that female participation is greater than male participation in pre-pond preparation and post-harvest phases (see Table 4.6). The pre-pond preparation stage includes collection of wild seed and sale to local shrimp farmers. Post-harvesting activities include peeling, processing and packaging shrimp for export.

Table 4.6
Gender Divisions in Shrimp Aquaculture Production Cycle

Phases in the Production Cycle	*Male, %*	*Female, %*
Pre-Production Stage: Collection of Wild Seed	18	82
Phase 1: Pond Preparation	74	26
Phase 2: Culture	85	15
Phase 3: Harvest	87	13
Post-Harvest Activities: Processing*	20	80

source: Hoon (1995); *Banerjee (1992); *Baud (1992)

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[38] Patil & KAA Database, 1997b; See Section 4.4.5 for discussion.

Data on participation by gender for smaller farms using less intensive technology was not collected in any of the three published studies, nor this one. However, according to discussions with small and marginal farmers, it is clear that female participation is required during the pond preparation and harvest periods. Small and marginal farmers rely almost exclusively on household labour during these periods.[39] This means that small and marginal farmers require females in the household to help repair bunds and at the end of the season, harvest the crop. It is likely, therefore, that non-corporate and smaller farms engage a higher proportion of women in each of the production cycles than the large and corporate farms. However, male workers as a percentage of the total work-force most likely dominate female participation rates.

4.4.5 A Survey of Labour Requirements

The average daily labour requirements needed for each production phase rise with farm size and production intensity (see Table 4.7). Larger farms are found to require greater daily labour inputs and therefore greater overall labour inputs (in person-days) across all three production phases (see Table 4.8).

Table 4.7
Average Daily Farm Labour Requirements (number of workers)

Size, S (WSA)	*PHASE 1* *Pond Preparation Phase* *no tractor** *tractor aided*	*PHASE 2* *Culture Period*	*PHASE 3* *Harvest Period*
marginal *S<1*	*2.0	1.0	3.0
small *1≤S<2*	*3.0 1.0	1.0	3.0
medium *2 ≤S<5*	2.3	3.2	4.1
large *5≤S<10*	4.6	7.3	6.7
corporate *10 ≤S*	14.5	25.6	9.9

source: Patil & KAA Database, 1997b

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[39] More detail regarding participation by gender is unavailable and therefore beyond the scope of this research.

Table 4.8
Average Total Labour Inputs Required (person-days) per Farm in Each Production Phase

Size, S (WSA)	*# Farms*	*PHASE 1: pond prep no tractor* tractor aided*	*PHASE 2: culture*	*PHASE 3:harvest*
marginal $S<1$	4	*14.0	117.5	4.5
small $1 \leq S<2$	6 4	**21.0* *7.0*	125.0 123.8	9.0 9.8
medium $2 \leq S<5$	34	16.3	400.1	21.6
large $5 \leq S<10$	21	32.7	965.5	52.3
corporate $10 \leq S$	13	116	3,760.0	211

source: Patil & KAA Database, 1997b

The average daily labour requirements are progressively larger for larger farms in each phase with the exception of the pond preparation phase with no tractor support. When tractors are used to aid small and marginal farmers in earthworks, fewer daily labour inputs are required. The fact that only farms of the smallest size forgo tractor support suggests that marginal farmers who cannot afford to hire a tractor substitute it for family labour. However, small and marginal farmers that did use tractor inputs often jointly hired tractor inputs. Similar behaviour was noted for medium size farmers.[40] Unlike in agriculture, Bullock labour is not engaged in preparing the shrimp pond since ploughing is not required. Shrimp farming does not require ploughing of any kind. General earthworks and bund preparation can only be accomplished using manual labour or tractor inputs. Shrimp farming is unique in this respect.

Intensity of Labour Use

To construct partial productivity ratios for labour use in each phase, the average total labour requirements in person-days for each farm is divided by the

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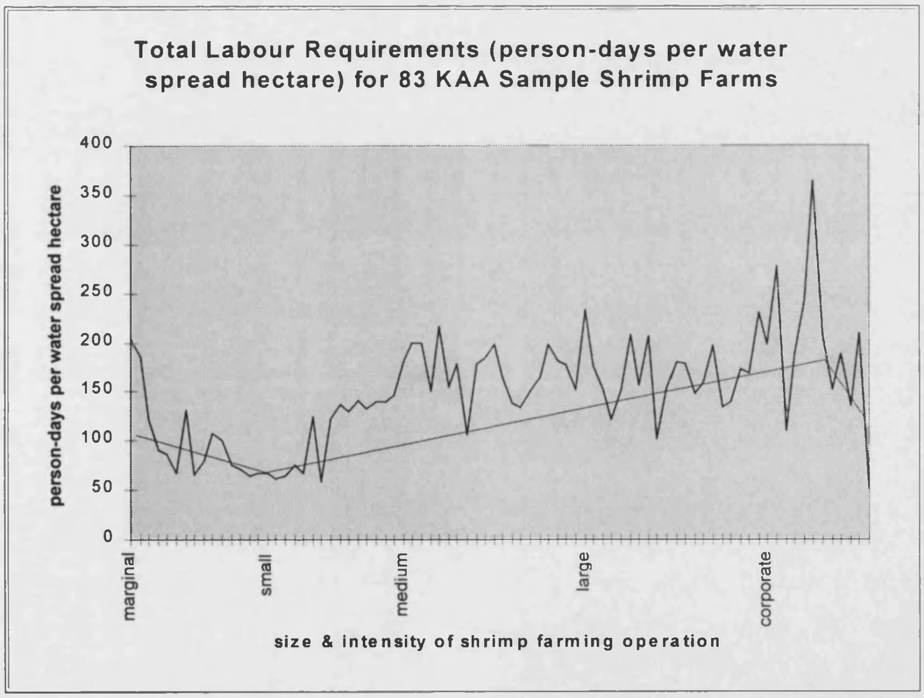
[40] The average work gained from one tractor is equivalent to between seven to fourteen person-days of human labour in this sector. Chapter 5 points out that farms using tractor inputs are more technically efficient than those that do not.

farm's water spread area in hectares. Labour input requirements (in person-days) per common unit farm area are thus determined without the farm size influencing the outcome. The results are presented in *Figure 4.0* and suggest that excluding marginal farmers without access to tractor inputs and the largest farms most intensively producing shrimp, total farm labour requirements increase with farm size and production intensity, keeping land size constant.

Capital intensive farms are generally found to be overall more labour intensive too per unit cropping area. However, the largest farms in the sample are found to use on average the same amount of labour in person-days per hectare than medium size farms. This suggests that the most capital intensive shrimp farms are moderately labour intensive. The mean trend is depicted by the black line in the diagram below.

Figure 4.0



The generally increasing trend of total labour inputs in person-days per hectare of culture area is influenced predominantly by labour requirements needed during the culture period. Labour inputs needed during this phase are approximately 88 percent of the average total labour requirements while pond preparation and harvest periods require only 6.5 percent and 5.5 percent of the average total labour requirements respectively. Labour requirements for pond preparation fall from 20.8 person-days per hectare for marginal farmers to roughly 5 person-days per hectare for farms greater than two water spread hectares.

Average labour requirements for the harvest period clearly increase with farm size and intensity. This is most likely a result of the fact that shrimp are a perishable good that need to be harvested quickly and packed in flaked ice to ensure high quality. Since the actual harvest is not automated, larger farmers tend to hire additional labour for this phase. A detailed breakdown of labour requirements is presented in Table 4.9.

Table 4.9
Total Labour Requirements
(person-days per water spread hectare)

Size, S (WSA)	*N*	*PHASE 1: pond prep* *no tractor** *tractor aided*	*PHASE 2: culture*	*PHASE 3: harvest*
$S<1$	4	20.8*	167.7	6.2
$1 \leq S<2$	6	14.4*	85.7	6.1
	4	3.8	66.3	5.2
$2 \leq S<5$	33	5.0	119.7	6.7
$5 \leq S<10$	21	5.1	148.2	8.2
$10 \leq S$	15	5.4	161.9	9.6

source: Patil & KAA Database, 1997b; N is the number of observations per category

Returns on Labour

Output per person-day is found to increase with technology intensity and farm size despite the fact that person-days per water spread hectare increases with farm size and intensity (Table 4.10).[41] Extensive farms produce approximately 4.1 kilograms per person-day of labour whereas intensive farms produce more than 3.5 times more at 14.6 kilograms per person-day.

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[41] In Chapter 3 it was shown that labour use per water spread hectare increases at a decreasing rate between small and large farms after which it increases at an increasing rate.

Table 4.10
Returns to Labour (y kgs/wsha/person-day)

Technology	*N*	*Average Farm Size (wsa)*	*Output in kilograms per person-day*
Extensive	38	3.37	4.10
Modified Extensive	22	5.09	5.19
Semi-Intensive	13	8.06	9.14
Intensive	9	38.6	14.60

source: Patil & KAA Database, 1997b

Permanent vs Temporary Employment

The labour contracts used in shrimp farming are not dissimilar to those used in agriculture. In this section the labour demand and supply mix for the KAA sample is discussed. On the demand side, the quantity of permanent and temporary employment needed by shrimp farms is estimated. On the supply side, the proportion of labour provided by family versus hired inputs from the local work force is estimated.

The demand for permanent and temporary workers for the 82 KAA farm sample varies by farm size. In total, approximately 438 unskilled workers from the local work force were employed or self-employed for approximately 7.2 days each in the pond preparation phase of the production cycle; 214 workers from the local work force were employed or self-employed for an average of 129 days in the culture period[42]; while for the harvest season, 478 semi-skilled and unskilled workers from the local work force were employed for an average of 8.02 days.

Permanent employment is available to approximately 214 individuals for an average of 144 days per crop cycle or 288 days per year for the 82 KAA farm sample. Of the 214 permanent workers, twelve are estimated to be self-employed small or marginal farmers (owner-operators) using mostly their own and family labour. Thus, approximately 202 permanent workers are hired from the local

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[42] Of the total 668 workers employed during this phase, only one third of the workers employed on farms of size five hectares or greater are from the local work force. Thus, the total estimated number of local workers employed from the rural labour market during this phase is 214.

work force. This is approximately 2.43 permanent workers per farm employed from the local work force in the sample.[43]

Temporary seven day employment per crop cycle or fourteen days annually is available for 224 workers during pond preparation and 264 workers for an average duration of eight days during harvest periods or sixteen days per year. This is temporary employment for 2.7 local workers per farm during the preparation phase and 3.18 local temporary workers per farm during the harvest period.

Hired vs Family Labour

The primary survey of 82 shrimp farms was not designed to isolate the actual amount of labour inputs hired from the local work force. Moreover, the responses to the survey questions do not distinguish whether additional workers are hired for a wage or are a member of the farmer's household, and therefore not paid a wage. It is possible to approximate the amount of hired labour, however, using some well known assumptions about the rural labour market and the results of semi-structured interviews of shrimp farmers. In this analysis, the following assumptions are therefore made. First, this analysis assumes that incremental labour used in small and marginal farms is provided by raising the labour participation within the cultivating household. With larger farms using more intensive technology, the incremental labour is provided by hired hands.[44] This is not unlike traditional Indian agricultural crops which follow this pattern (Acharya, 1992: 169).

Survey data suggest that 49 percent of KAA farms are less than two hectares of water spread area in size and owned and operated by small and marginal shrimp farmers. The assumption that self-employed owner-operators that predominantly use extensive culture technology almost always use family labour for pond preparation and harvest phases of the production cycle, is not

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[43] Since 214 permanent workers are needed for the culture phase which is of largest duration, it is assumed that these workers are hired in the first and third phases too.

unreasonable.[45] Moreover, larger farms greater than two water spread hectares by contrast are assumed to rely on hired temporary and permanent hands for all three phases of the production cycle (see Table 4A.1 in the Appendix).

Based on the above mentioned set of assumptions and extrapolation, the following labour inputs were needed by the 518 KAA shrimp farms during the second crop cycle of 1996. The 518 KAA farms offered permanent employment for 1,162 workers from the local work force. Of the 1,162 permanent jobs, 290 or twenty-five percent are estimated as self-employed owner-operators. Thus, 872 individuals or seventy-five percent were hired directly from the local labour force for permanent annual employment.[46] This amounts to approximately 2.24 total permanent workers per KAA farm employed from the local work force of which 1.68 were permanent hired workers.

4.4.6 Employment in Agriculture vs Aquaculture

In Table 4.11 we compare the amount of unskilled labour employed in six primary crops grown in Andhra Pradesh with the estimated labour requirements of shrimp aquaculture. Crop specific figures show that sugarcane, paddy and shrimp employ more labour inputs per hectare cropping area than groundnut, *jowar*, *moong* and *urad* in Andhra Pradesh. The high labour use in certain crops is highly correlated with the fact that these crops are grown under irrigated or high rainfall conditions; crops requiring fewer labour inputs per sown hectare are grown under relatively dry conditions (Acharya, 1992:170).

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[44] Based on discussions with farmers of all sizes in Bestapalem and Tikkavaram shrimp farming region.

[45] Based on informal interviews with small and marginal farmers.

[46] This assumption is based on the answer to the question: how many individuals work on your farm during the culture period (include yourself)? Each of the farmers operating on areas less than two water spread hectares in size answered "1" suggesting that they are the farm's sole permanent employee.

Table 4.11
A Comparison of TOTAL and HIRED Labour Inputs per Crop for Seven Crops Cultivated in Andhra Pradesh

Agricultural Crop	Total Unskilled Labour Inputs (person-days per sown hectare)	Hired Unskilled Labour Inputs (person-days per sown hectare)
Paddy	173.56	142.95
Jowar	57.73	38.9
Sugarcane	359.63	320.81
Moong	62.39	44.59
Urad	47.52	38.49
Groundnut	98.59	76.14
*Shrimp	149.59[47]	134.09[48]

*Patil & KAA Database, 1997b; 1980-1990 Cost of Cultivation Survey data of 9,000 farms compiled by Acharya (1992).

According to survey data, Shrimp culture utilises on average, 149.59 total person-days per hectare per season of which 134.09 person-days are hired labour inputs.[49] This is a close third to paddy cultivation which requires on average 173.63 total person-days per season of which 142.95 person-days are locally hired labour inputs. Labour inputs for paddy and shrimp can be directly compared as both are bi-annual crops. Our estimate suggests that there is a difference of 23.56 person-days per hectare per crop or 47 person-days per hectare per year labour use difference between paddy and rice farming. This further suggests that converted paddy land to shrimp farming does indeed imply a loss of employment per sown hectare in Andhra Pradesh. However, the same may not be said about other agricultural crops or agriculture in general.

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[47] Calculated from summing total person-days per water spread area for each of the farms in our sample and dividing by 82, the number of shrimp farms in the KAA sample. This figure is the average total labour-days of input required per water spread hectare.

[48] This figure is calculated by summing total person-days per water spread hectare for all farms greater or equal to 2 hectares of water spread area and dividing by 82, the total shrimp farms in the sample. Based on semi-structured interviews of the KAA sample and well known assumptions about the rural labour force, the following assumptions can be made: All farms greater than two water spread hectares in size use hired labour only. Owners of these farms serve as managers and not labourers. This is in contrast to farms under two water spread hectares in size where owner-operators serve as workers.

[49] This is based on shrimp farms culturing two times per year and amounts to 80 percent of the total labour inputs required by all farms, on average.

4.5 Conclusion

It is clear that shrimp farming has made some impact on the pattern of land use and consequently, employment opportunities for coastal inhabitants in the rural labour market. Fertile agricultural land, pasture and grazing areas and wasteland have each been converted to some degree for the purpose of shrimp farming. Land located directly adjacent to brackishwater rivers have in most cases been leased and sold by private agents or the government. In some cases, these areas have been encroached upon by shrimp entrepreneurs. Given the several thousand kilometers of coastal land, government enforcement has been difficult (BFDA, 1997). It is less clear, however, what direct impact shrimp farming has had on the number of owner-cultivators and tenant farmers engaged in agriculture at the district and mandal levels.

Primary data collected from a sample of Kandaleru shrimp farms suggest that shrimp farming requires fewer person-days of labour per year than rice farming. This finding supports the allegations made by NGOs and underscores the documentation presented before the Indian Supreme Court. However, since a minority of the total land area converted to shrimp farms is fertile agricultural land, the loss of employment to rural inhabitants may not be of little consequence. This is further supported by the fact that thousands of shrimp farms operating in the district have created rural employment opportunities available to local people where previously there were none.

Appendix 4A

Table 4A.1
Total & Hired Unskilled/Semi-skilled Workers Employed from Local Workforce

		PHASE I		PHASE 2		PHASE 3	
Production Intensity	*Mean Size (wsa)*	*Total*	*Hired*	*Total*	*Hired*	*Total*	*Hired*
Extensive[a]	.6	23.3	0	175	0	5.0	0
Extensive[b]	3.45	6.8	0	123.1	0	7.2	0
Modified Extensive	5.09	5.39	5.39	133.8	133.8	7.8	7.8
Semi-Intensive	8.06	5.11	5.11	141.6	141.6	6.9	6.9
Intensive	38.6	5.48	5.48	174.2	174.2	11.7	11.7
AVG	8.39	6.2	5.32	135.1	144.3	7.78	8.3

source: Patil & KAA Database, 1997b; estimates based on KAA Survey responses and weighted by the number of farms per category. Notes: [a] smallest two extensive farms; [b] all remaining extensive farms.

Table 4A.2
Total & Hired Unskilled and Semi-skilled Workers Employed from the Local Workforce & Average Duration of Phases

		PHASE I			*PHASE 2*			*PHASE 3*		
Size, S	*N*	Total	Hired	Avg. days	Total	Hired	Avg. days	Total	Hired	Avg. days
S<1	210	420	0	7	210	0	118	630	0	1.5
1≤S<2	80	160	0	7	80	0	123	240	0	3.1
2 ≤S<5	139	323	0	7	442	0	124	570	0	5.1
5≤S<10	54	251	251	7.1	131	131	129	362	362	7.7
10 ≤S	35	508	508	8.1	299	299	136	346	346	16.9
KAA	518	1,662	759	7.32	1,162	430	128	2,148	1,008	9.1

source: Patil & KAA Database, 1997a,b; N=number of farms ; workers for phases 1 & 3 calculated by multiplying average daily labour requirements in number of workers per phase for the 82 farm sample by N in each category. Phase 2 is calculated similarly except for categories of farm size greater or equal to five hectares. In this case, we took one third of the total because large and corporate farms utilise 66 percent of their own permanent labour who are brought in from outside the region.

Part II

Evaluating Indian Shrimp Farm Performance

Introduction

The lack of information on productive efficiency and the environmental impacts of shrimp farms in India has become of major national importance as a result of the Indian Supreme Court's December 1996 decision to ban the shrimp farming sector. The ban was a direct result of concerns raised over the impact of shrimp farming—in terms of its degradation of the environment and marginalization of local people from coastal resources. Subsequent to the Supreme Court ruling, the Indian parliament raised the issue of devising appropriate regulation of the sector to ensure its overall sustainable development. In this context, the 1997 Aquaculture Authority Act which calls for a special committee to devise guidelines for sustainable shrimp farming was approved by Parliament in March 1997.

In addition to questions raised regarding the nature and extent of environmental and socio-economic externalities of this sector, the recent parliamentary debate has raised equally important questions regarding the sustainability of shrimp farms under a variety of production methods. India's coastal inhabitants have engaged in traditional paddy cum shrimp farming for centuries, unblemished by negative environmental or social consequences. Traditional shrimp farming methods are exempt from the ban. Extensive, modified extensive, semi-intensive and intensive farming practices are currently under review. The current belief is that more intensive methods of production are more likely to result in ecological disasters similar to those exhibited in other parts of the world. This is primarily because of over-stocking and consequently over-feeding.

It is simple to pollute the environment. Farmers push up intensity levels by raising stocking densities and feed inputs per unit pond area. Over-feeding in conjunction with high stocking densities can result in pollution of the delicate pond environment which ultimately leads to shrimp disease. A farmer facing disease is forced to either harvest early (if there is early enough detection of the disease) or ends up losing the entire crop. Either way, the polluted pond water is then discharged from the farm into a common waterway shared by all shrimp farmers in that location. This has two major consequences. First, polluted pond water is discharged into the "commons" and is used as fresh intake water by downstream shrimp farmers. This infects the downstream farmer's crop. It is a classic upstream-downstream externality problem. Second, polluted discharge water pollutes the common waterway with dire consequences to plant and fish species and other marine biodiversity. In addition, there are spill-over effects to the local inhabitants who rely on these species as a source of food or income generating activities. Naturally, the Indian government is concerned. These concerns, however, are wanting in representative data and methodologically sound economic analysis.

By exploring the production methods of shrimp farmers it is possible to determine characteristics common to efficient farms. That is to say, which farms use the minimum combination of inputs to maximise output. Using a parametric approach to measure farm efficiency, it is possible to determine which managerial practices may improve efficiency and those that may reduce it. However, in absence of panel data, it is only really possible to say what are the characteristics of efficient and inefficient farms at one snap-shot in time. Identification of the best practice farm size and issues of scale economies in the shrimp farming sector are equally important. For example, are larger farms generally more efficient than smaller farms, or do smaller farms have the advantage with respect to overall efficiency, and why? Finally, with non-parametric analysis it is possible to estimate which farms are over-stocking and over-feeding and by what quantity.[1] This begs an answer to the following questions raised by policy makers: (i) Are farms which adopt less intensive culture methods more or less efficient than those engaged in more intensive practices? (ii) What is ultimately the relationship between efficiency and environmental sustainability? With respect to the current regulatory debates on brackishwater shrimp farming, answers to these questions are imperative if shrimp aquaculture is to develop along a sustainable path.

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[1] This is in relation to the theoretically most efficient combination of the inputs.

General Methodology, Model Estimation & Efficiency Measures

Technical efficiency refers to a firm's ability to produce the maximum possible output from a given combination of inputs and technology--regardless of market demand and prices--with the production environment taken as given. The efficiency index is measured as the ratio of the observed output of a farm to the maximal potential output or *frontier* output by that farm given its cultivating environment. The reliability of this index therefore depends on accurately estimating the maximal potential output of a farm or the minimum input combination needed to produce a given level of farm output.

There are two primary methods used to estimate the efficiency of farms: a non-parametric approach called Data Envelopment Analysis (DEA); and a parametric Frontier Production Function (FPF) approach (see *Figure II)*. The choice of parametric or non-parametric models to measure farm efficiency depends on economic behavioural assumptions of both methods and data constraints. The efficiency indices generated by the parametric production frontier approach are obtained by estimating the best practice frontier using maximum likelihood techniques. The parametric approach has several advantages, including its capacity to provide significance tests for inputs and an overall goodness of fit for the model. One disadvantage of this approach is that the functional form may be incorrectly specified and therefore yield inappropriate efficiency indices.

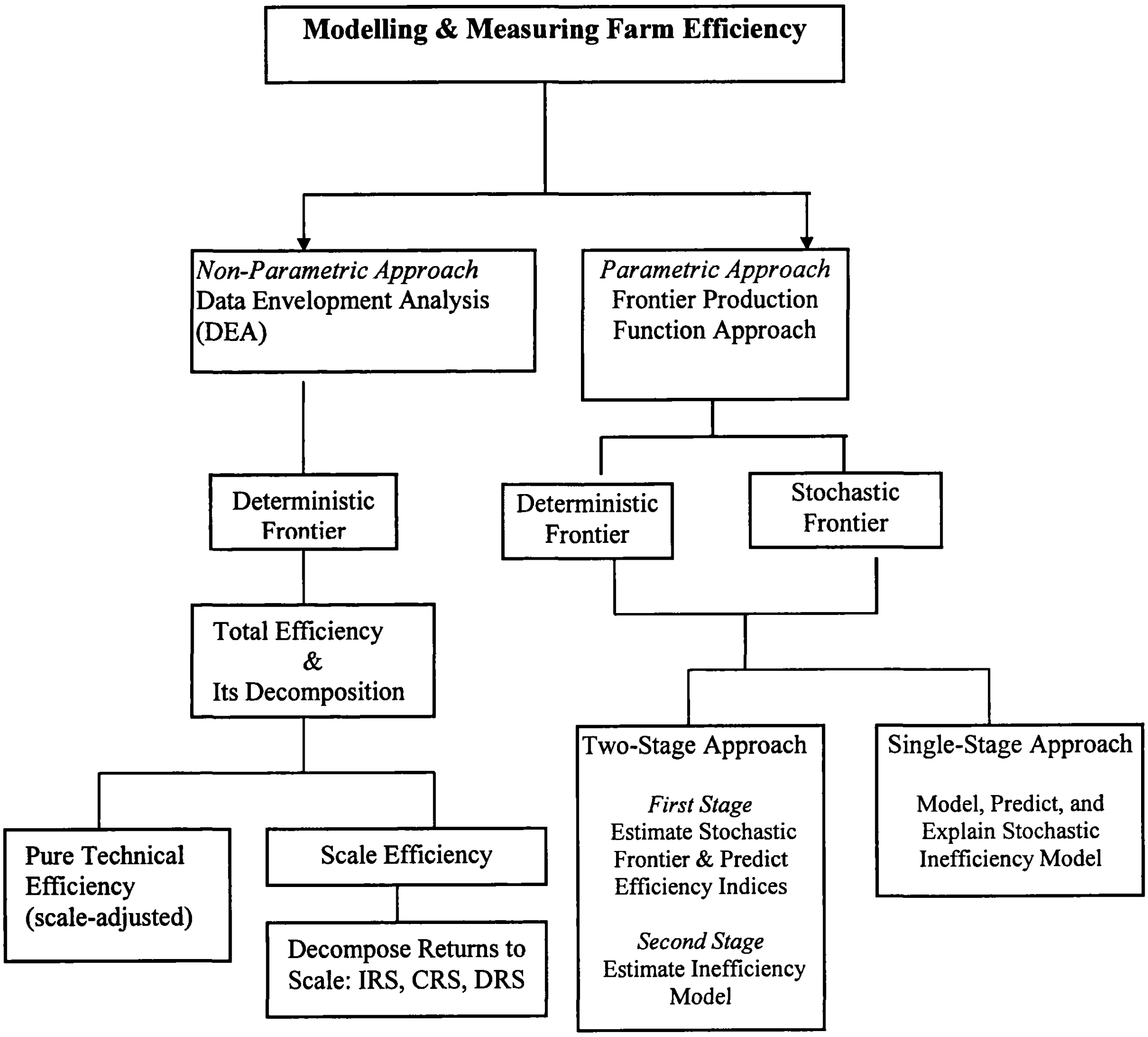
The non-parametric frontier is deterministic in nature and constructed from a linear programming model. The model is capable of handling zeros in the input mix and does not include a disturbance term to capture noise. The efficient frontier is constructed from the solutions of each linear programming problem which minimises inputs in the production process for a given output level. The efficiency level of each farm is calculated relative to this frontier as the ratio of actual to potential performance. One clear advantage of the non-parametric model is its ability to separate scale effects from total efficiency. It also does not impose an arbitrary functional form. DEA results are however swayed by outliers and there are no significance tests for inputs or an overall measure for goodness of fit. Nonetheless, the model's overall appeal is simply that it allows the comparison of each firm with a given input-output combination with others in the sector in different proportions. Given each method's own restrictive assumptions, in this analysis of the efficiency of the Kandaleru region's brackishwater shrimp farms, both methods are employed to fully explore the issue of efficiency.

First, a well navigated *parametric* approach to measuring technical inefficiency is discussed in Chapter 4. In this chapter, technical efficiency in Indian shrimp farm production is modelled, measured and explained by estimating a restricted Translog stochastic frontier production function on cross sectional data from 82 farms operating along the Kandaleru river during the second crop cycle of 1996. Maximum-likelihood methods are employed for the estimation of Cobb-Douglas and Translog production functions and the prediction of technical efficiency. Results of the generalised likelihood ratio test suggest that the stochastic Translog specification is preferred to the nested Cobb-Douglas frontier. This conclusion is found to hold for both two-stage and single-stage modelling approaches presented in this paper.

The variation of technical efficiency indices across the 82 shrimp farm sample is explained using farm specific characteristics and managerial variables. The results suggest that the use of tractor inputs in pond preparation and daily water exchange practices during the culture period is found to increase efficiency. A large average pond size and a greater number of ponds per farm (i.e. big farms) are found to be determinants of inefficiency. Additionally, location (a proxy for water quality) is found to be an important variable in explaining technical inefficiency.

Next, in Chapter 5, Data Envelopment Analysis confirms that the scale of operation and technical competence are crucial factors in explaining Kandaleru shrimp farm efficiency. Following Fare et al. (1985) pure technical and scale efficiency are extracted from the Farrell (1957) total efficiency index. An inverse relationship is found to exist between farm size and efficiency in South Asian shrimp farming. The results suggest that while small and medium size farms are on average technically efficient, they remain largely scale inefficient. Scale inefficiency means that farms are not culturing at an optimal size of operation to ensure maximum total efficiency. This further suggests that if farms were size-adjusted, overall efficiency could increase. While large and corporate size farms are on average scale efficient, they remain largely technically inefficient. The policy direction is clear: generally, larger scale farmers must reduce the overall intensity of culture operations to maximise efficiency, minimise input slacks and reduce environmental degradation both within the aquatic culture environment and the natural ecosystem. The smallest farms could increase efficiency by enlarging their farm size and increasing the combination of inputs in the same proportion as their current culturing operations.

Figure II



Chapter 5

Modelling, Measuring & Explaining the Inefficiency of Brackishwater Shrimp Farms in South-eastern India

-A Parametric (Stochastic Frontier Production Function) Approach-

5.0 Introduction

The stochastic frontier production function approach (PFA) is used to model productive efficiency in the shrimp farming sector. This approach models the production technology used to culture shrimp, measures the technical inefficiency of 82 shrimp farms operating along the Kandaleru river and explains their inefficiency.

The stochastic approach to estimating the technical efficiency of farms was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977). The method assumes a parametric technology and uses statistical techniques to estimate the maximum potential output from a given combination of inputs for each farm in a given sample. The greater the amount by which the realised output falls short of this stochastic frontier, the greater the level of inefficiency attributed to each farm. Following the development of the theoretical model, a large empirical literature has developed. Widespread empirical prediction of the technical efficiencies of individual firms became possible as a result of Jondrow et al. (1982).

Inefficiency effects can be empirically modelled using either a two-stage or single-stage approach. In this chapter, both methods are explored. First, the theoretical stochastic production frontier model proposed by Aigner et al. (1977) and modified by Stevenson (1980) is discussed using a two-stage approach. In the first stage, the stochastic production function is estimated with a composed error structure. In the second stage, farm-specific variables are regressed on the predicted efficiency measures. Next, the single stage approach—based on Aigner et al. (1977) but further developed by Battese and Coelli (1988)—is followed. In this approach, the inefficiency effects are modelled as an explicit function of farm-specific variables that are believed to influence the level of technical inefficiency. The differences between these two approaches are further discussed throughout this chapter.

This chapter consists of ten sections. In Section 5.1 the empirical applications of stochastic frontier production methods as a parametric approach to measuring technical efficiency in cross sectional data are surveyed. Sections 5.2 to 5.5 present the overall methodology used in this investigation of shrimp farm production and technical efficiency. First, the two different parametric approaches to model stochastic frontiers and estimate the technical inefficiency of shrimp farms are described. Next, the hypothesis testing methodology employed to test between various specifications of the general stochastic frontier considered (i.e. Cobb-Douglas and Translog frontiers) is presented. Section 5.6 presents a brief overview of the data. Section 5.7 presents the model specifications and estimation results for the two-stage method. Section 5.8 presents the single-stage estimation results. Section 5.9 outlines policy implications of the results that may help guide the current Indian regulatory debates. Section 5.10 concludes and suggests areas for further research.

5.1 An Overview of the Literature

Stochastic frontier production function models have been employed in a number of empirical studies in an agricultural context. Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977) are accredited with first applying stochastic frontier production functions to aggregate data on US agriculture and French manufacturing industries, respectively. Both papers conclude that the stochastic frontier was not significantly different from the average response function, OLS. Battese and Corra (1977) presented the first application of the stochastic frontier model to farm level data. They estimated deterministic and stochastic Cobb-Douglas production frontiers on data from the 1973-74 Australian Grazing Industry Survey and found that the stochastic specification was significantly different from the corresponding deterministic frontier. They did not address the issue of technical efficiency in this paper.

Many of the pioneering initial studies that addressed the issue of technical efficiency have employed a two-stage modelling approach to estimate the stochastic frontier model and predict technical efficiency measures in the first stage and explain technical inefficiencies in the second. The first stage involves the specification and estimation of the stochastic frontier model and the prediction of technical efficiency effects. The second stage involves specifying a regression model for the level of technical efficiency of farms/firms in terms of various explanatory variables and a random error. The parameters of the second stage inefficiency model have generally been estimated using ordinary least squares (OLS) regressions.[1] More recently, however, empirical studies specifying a stochastic frontier are adopting the single-stage estimation procedure.[2] In this overview of the literature we summarise only the most important empirical studies that have built upon the Aigner et al. (1977) foundation for the empirical estimation of stochastic frontiers to predict technical efficiency and explain inefficiencies. These studies serve as the foundation for our empirical investigation of Kandaleru shrimp farms.

Early empirical studies addressing the issue of technical efficiency measurement and its explanation adopted the two-stage modelling approach. Using data collected from 70 rice farmers in India, Kalirajan (1981) estimated a stochastic Cobb-Douglas production function. This study found that the variance of farm effects were highly significant in describing the variability of rice yields in the sample. The difference between the estimated 'maximum yield function' and the observed rice yields by examining variables such as farmer's experience, educational level, number of visits by extension workers, etc. were then investigated in a second stage model. This paper concludes by suggesting policy changes directed at improving farmers' crop yields.

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[1] A notable exception is found in Kalirajan (1981) who specifies that the random errors in the second stage inefficiency model as having a half-normal distribution.

[2] Several recent papers, however, still use the two-stage approach due to the relative ease in which the first stage stochastic frontier model and second stage inefficiency model can be estimated. Single-stage estimation techniques have required the investigator to employ linear programming techniques which are cumbersome and time consuming. However, the recent development of computer software and specialized programs to estimate stochastic frontiers and the inefficiency effects in a single framework has made the task less daunting.

Kalirajan and Flinn (1983) specified a Translog stochastic frontier production function in their analysis of the technical efficiency of 79 rice farmers in the Philippines and estimated the parameters of the model using the maximum likelihood method. The nested Cobb-Douglas specification was found to be an inadequate representation of the farm level data. In the second modelling stage, the predicted technical efficiency measures were regressed on farm level variables and farmer characteristics and found that the practice of transplanting rice seedlings, the incidence of fertilisation and the number of years of farming experience were all significant in influencing technical efficiency.

Huang and Bagi (1984) estimated a Translog stochastic frontier production function using the data set from Bagi (1982).[3] They concluded that the stochastic Cobb-Douglas specification did not adequately represent the data as the Translog specification was tested and preferred. Next, they predicted the individual farm technical efficiencies using the technique presented in Jondrow et al. (1982).

Kalirajan and Shand (1986) investigated the technical efficiencies of rice farmers producing in Malaysia within the Kemubu Irrigation Project boundaries and outside of it. The stochastic Cobb-Douglas model was rejected in favour of the more flexible Translog specification which seemed to represent the data more adequately. Using maximum likelihood estimation methods, the estimated parameters were found to be significantly different between both groups of farmers and that those farmers outside the project area had more narrowly distributed efficiency measures. They concluded that improved technology does not necessarily result in improved technical efficiency.

Kalirajan (1989) used the two-stage estimation method to predict technical efficiencies of individual rice farmers in two different regions in the Philippines. The two-stage estimation technique was used to discover what farm specific characteristics had significant effects on the variation in the technical efficiencies. The stochastic Cobb-Douglas frontier was assumed appropriate in their analysis of the first estimation stage.

Baily, Biswas, Kumbhakar and Schulthies (1989) estimated a stochastic model involving technical, allocative and scale inefficiencies for cross-sectional data on 68 Ecuadorian dairy farms. They discovered that although technical inefficiencies between farmers was only twelve percent, the loss in profits due to the inefficiencies ranged from twenty to twenty-five percent.

More recent empirical studies that estimate a specified stochastic frontier model and predict the technical inefficiency of farms do so using the single-stage estimation procedure. This is a result of a fundamental contradiction of assumptions necessary to estimate production functions using the two-stage technique (Battese and Coelli,1995). In the first stage, technical efficiency is assumed to be identically distributed. In the second stage, however, technical efficiency is specified as a function of several explanatory variables. This contradicts the first stage assumption suggesting that the technical efficiency is identically distributed. Battese and Coelli (1995) overcome this contradiction by suggesting a method to estimate the parameters of the stochastic production frontier and the inefficiency model--given that the technical inefficiency effects are stochastic--in one-stage.

Early empirical studies that estimate stochastic frontier models, predict technical efficiency and explain inefficiencies in the single-stage framework include Reifschneider and Stevenson's (1991) study of electricity generation in the United States and Huang and Liu's (1992) investigation of the electronics industry in Taiwan. Both studies were based on cross sectional data. Battese and Coelli (1992, 1995) extend Huang and Liu's (1992) model and define a stochastic frontier production function for a panel of Indian paddy farmers and are thus able to examine changes in efficiency over time. Battese et al. (1996) examine the efficiency of Pakistani wheat farmers in four districts.

Although the empirical literature on measuring and explaining technical efficiency covers a wide variety of applications on farming and manufacturing data (both aggregated and farm/firm specific), there has been no application to brackishwater shrimp farming to date. Our empirical examination of Kandaleru

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[3] Bagi (1982) specified the stochastic Cobb-Douglas production function model to determine the average technical efficiency of small and large crop farms and mixed-enterprise farms in the

shrimp farms is therefore a first in modelling shrimp farm production, in predicting technical efficiency measures and in explaining the inefficiencies existing in Kandaleru shrimp production.

5.2 General Production Frontier Models

5.2.1 *A Stochastic Frontier Model*

The general stochastic frontier production function is defined by,

$$(1) \quad Y_i = f(x_i\,;\beta)\,exp\,(V_i - U_i) \qquad i=1, 2,\ldots,N.$$

where Y_i is the level of output of the i^th^ firm, $\mathbf{x}_i$ is a k×1 vector or transformations of the input quantities of the i^th^ firm; β is a vector of unknown parameters; N is the number of observations in the sample; the V_i is a random error assumed to be independently and identically distributed (iid) $N(0,\sigma_V^2)$ and which include measurement errors in production, weather and other random factors not under the control of the firm. It is independent of the U_i which are assumed to account for technical inefficiency in production and are assumed to be non-negative truncations of the iid $N(\mu,\sigma_U^2)$ distribution. Taking the natural log of both sides of equation (1) yields,

$$(1a) \quad ln\,(Y_i) = f(x_i\,;\beta) + (V_i - U_i)$$

with all variables as previously defined.

In the Aigner, Lovell and Schmidt (1977) specification, the U_i are assumed to be distributed $|N(0,\sigma_u^2)|$, the half-normal distribution. Stevenson's (1980) specification of the distribution of the U_i includes cases in which there may be a low probability of obtaining U_i close to zero (i.e. the case where their is severe technical inefficiency present in the sample firms) such that $\mu \neq 0$. The Y_i

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Western Tennessee, USA and found no significance differences between them.

are bounded above by the stochastic quantity $f(x_i ; \beta) \exp (V_i)$ which gives the stochastic frontier model its name. The general specification of $f(.)$ in (1) requires a particular choice of functional form such as the Cobb-Douglas or Translog. Both of these stochastic frontier models are considered in this empirical investigation of efficiency in the shrimp farming sector.

5.2.2. A Deterministic Frontier Model

The general deterministic frontier model is defined by,

$$(2) \qquad Y_i = f(x_i ; \beta) \exp (- U_i)$$

where x_i, β are as earlier defined. The presence of the non-negative random error U_i is associated with the firm specific factors which contribute to the ith firm not attaining maximum efficiency of production. U_i is associated with the technical inefficiency of farm *i* and implies that the value of the random variable, $\exp (- U_i)$ is bounded between zero and one. This implies that the possible production Y_i is bounded by a non-stochastic or deterministic quantity, $f(x_i;\beta)$. The technical efficiency for deterministic models is defined as the factor by which the observed level of production of the firm is *less* than its frontier output.

The central difference between the stochastic and non-stochastic frontier models rests in the construction and interpretation of the error term. In *stochastic* models, the error term is constructed to have a random component, V_i associated with random factors such as weather and an independent U_i which is assumed to be non-negative truncations of the $N(\mu, \sigma^2)$ and associated with farm inefficiency. In *non-stochastic* or deterministic frontier models, the random error term U_i defined above is not decomposed further. Additionally, inference of the β parameters in the deterministic model cannot be obtained from the maximum likelihood estimators because the regularity conditions are not satisfied in this model (see Theil, 1971:392). For a given set of data, the estimated technical efficiency measures obtained by fitting a deterministic frontier are less than those obtained by estimating the stochastic frontier since the deterministic frontier is estimated such that no output values exceed it (see Battese, 1992:188).

5.2.3 *Inefficiency Effects*

Following Battese (1992), the basic structure of the stochastic frontier model (1) in which the productive activity of two farms represented by i and j is considered. In *Figure 5.0,* farm i uses a combination of inputs described by vector $\boldsymbol{x}_i$ and obtains output Y_i. The maximum possible output or frontier output given its inputs is Y_i^*. In this case, farm i exceeds the output value associated with the deterministic frontier $f(x_i;\beta)$ and the random error V_i is positive. This is a result of the favourable conditions associated with the productive activity of farm i not directly under the farm's control. Similarly, farm j uses a combination of inputs described by vector x_j and obtains output Y_j which has a corresponding frontier value Y_j^*. In this case, farm j falls below the output value associated with the deterministic frontier $f(x_i;\beta)$ and the random error V_i is negative. This is a result of the unfavourable conditions associated with the productive activity of farm j not directly under the control of the farm. In both cases, the production values for both farm i and farm j are less than the corresponding stochastic frontier value.[4] The level of inefficiency for farm i can therefore be pictorially represented by the distance between the stochastic output Y_i^* and the realised output Y_i. The same applies for farm j.

Given the assumptions of the stochastic frontier model (1), inference on the model's parameters are based on maximum likelihood estimation since the standard regularity conditions hold.[5] Aigner et al. (1977) suggest that the maximum likelihood estimates of β could be obtained using the parameterization, $\sigma^2=\sigma_V^2+\sigma_U^2$ and λ, where $\lambda=\sigma_u / \sigma_v$, the ratio of the two standard errors. Battese and Corra (1977) innovate on λ and suggest,

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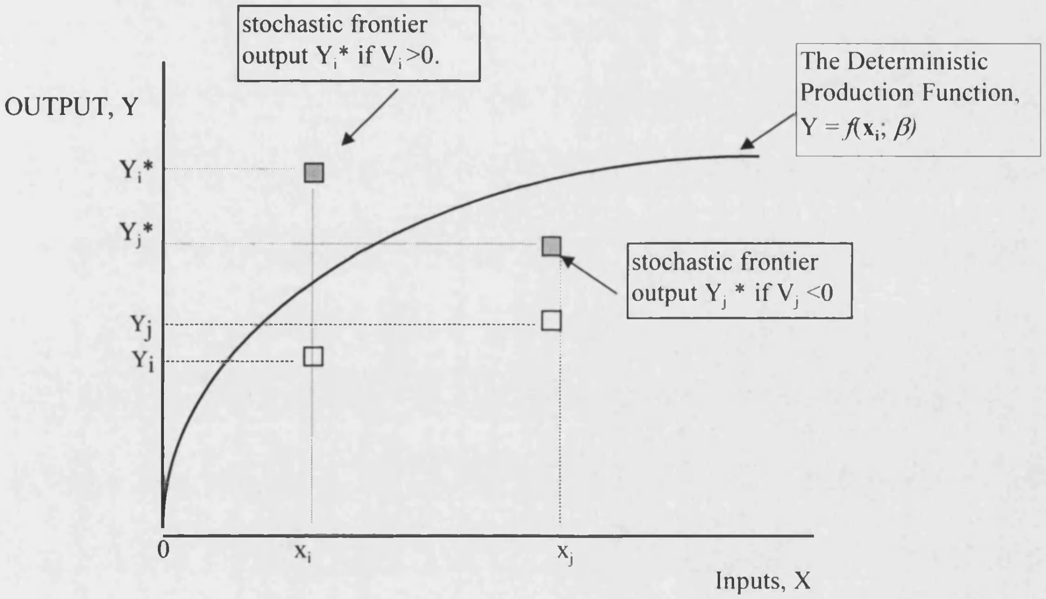
[4] The case where both the observed (Y_i) and frontier production (Y_i^*) values fall above the corresponding value of the deterministic production function is possible but is not illustrated in our example for simplicity.

(3) $\gamma = \sigma_U^2/(\sigma_V^2+\sigma_U^2)$

such that $0 \leq \gamma \leq 1$. The parameter γ is defined as the total variation in output from the frontier which is attributable to technical inefficiency. This parameterisation is used in our estimation of technical efficiency.[6]

Figure 5.0



Note: For a given set of data, the estimated technical efficiencies obtained by fitting the deterministic frontier will be less than those obtained by fitting a stochastic frontier since the deterministic frontier is estimated such that no output values exceed it.

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[5] See Theil (1971) for a detailed discussion of the necessary properties needed to conduct maximum likelihood estimation.

[6] The parameters of the model described above may be estimated by the method of maximum likelihood.

5.3 Measuring Technical Efficiency (Stochastic Frontier Models)

This section describes the development of technical efficiency measures in stochastic frontier models, describes how the measures are calculated empirically and suggests possible model specifications for Kandaleru shrimp production. Generally, the technical efficiency of any given farm can be defined by the ratio of the observed output, Y_i to the corresponding frontier output, Y_i^*, conditional on the level of inputs used by the farm. Thus, the technical efficiency of farm *i* is generally described by,

$$(4) \quad TE_i = Y_i / Y_i^*$$

$$= f(x_i; \beta) \exp(V_i - U_i) / f(x_i; \beta) \exp(V_i)$$

$$= \exp(-U_i)$$

where each variable is as previously defined in Section 5.2. Jondrow et al. (1982) is credited with first obtaining empirical predictions of technical efficiency measures at the individual firm level for a defined stochastic production function. Assuming that the U_i have a half-normal and exponential distribution, Jondrow et al. (1982) predicted the technical efficiency of the *ith* firm by taking the expected value of U_i conditional on the stochastic error term $(V_i - U_i)$. These authors devised the following formulae, $1 - E(U_i \mid V_i - U_i)$ to predict the level of technical inefficiency of the i^{th} firm. However, Battese and Coelli (1988) suggest that technical efficiency of the i^{th} firm, $TE_i \equiv \exp(-U_i)$ is perhaps best predicted by using the conditional expectation of technical efficiency, $\exp(-U_i)$, given the value of the random variable, $E_i \equiv V_i - U_i$ when the functional form is in logs.[7] They suggest,

$$(5) \quad TE_i = E(Y_i^* \mid U_i, X_i) / E(Y_i^* \mid U_i = 0, X_i)$$

where, $Y_i^* = \exp(Y_i)$ when the dependent variable is logged. The Technical Efficiency Index (TE_i) is bounded by zero and one such that $0 < TE_i < 1$. In this investigation, the Battese and Coelli (1988) method is adapted to include Stevenson's (1980) model for the U_i. This specification is then used to calculate predictions of each shrimp farm's technical efficiency.[8]

5.4 Model Specification & Estimation Procedure

As discussed earlier, there are two methods with which to theoretically and empirically model inefficiency effects defined by our general stochastic production frontier model presented in (1). This section presents formal models for each approach. Section 5.4.1 discusses the two-stage estimation procedure while Section 5.4.2. models the single-stage estimation procedure. Both methods are developed with respect to cross sectional data.

5.4.1 Two-Stage Estimation Procedure

Following Pitt and Lee (1991) it is possible to identify and explain predicted farm inefficiency measures for an 82 shrimp farm cross section using a two-stage estimation procedure. In the first stage, we estimate the stochastic frontier production with a composed error structure defined in (1) and predict farm level efficiencies using the estimated functions discussed in the previous section. The one-sided component, $U_i \geq 0$ reflects technical inefficiency relative to the stochastic frontier $Y_i = f(x_i ; \beta) exp(V_i)$. Theoretically, U_i=0 for any production unit whose output lies *on* the frontier (i.e. the case where there is no technical inefficiency) and U_i>0 for any realised output lying below the frontier.

In the second stage farm-specific explanatory variables such as managerial and farm characteristics are regressed on the predicted efficiency measures. The efficiency effects can therefore be defined by,

$$(6) \qquad TE_i = \mathbf{z}_i\delta + e_i \; ; \quad i = 1,2,\ldots n$$

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[7] This distinction arises as a result of estimating multiplicative production frontier models (see Battese and Coelli, 1992).

[8] This formulation relies on the value of the unobservable U_i being predicted.

where TE_i is the technical efficiency index of the ith farm predicted in the first stage estimation procedure, z_i is a (1xm) vector of farm and managerial specific variables (i.e. socio-economic and demographic variables); δ is an ($m \times 1$) vector of unknown coefficients of the farm and managerial specific variables; and the e_i are independently distributed random errors which are assumed to be non-negative truncations of the iid. $N(\mu, \sigma_e^2)$. From this second stage regression, it is possible to determine which farm specific variables are statistically significant in explaining technical inefficiency. This two-stage estimation procedure differs from the single-stage approach where both the β_i and δ_i are estimated in a single equation estimation procedure. This is discussed next.

5.4.2 Single-Stage Estimation Procedure

The two-stage estimation technique is recognised as a procedure which is inconsistent in it's assumptions regarding the independence of the inefficiency effects in the two estimation stages. Battese and Coelli (1995) point out that the first stage technical efficiency indices are assumed to be identically distributed, while the second stage specifies the indices as a function of farm-specific variables. The identical distribution assumption of the first stage is therefore contradicted. Thus, the two stage procedure is unlikely to provide estimates that are as *efficient* as those that are obtained using a single-stage estimation procedure (Kumbhakar et al., 1991). Nonetheless, the two stage method continues to be applied in the empirical literature.[9]

Kumbhakar et al. (1991), Reifschneider and Stevenson (1991) and Huang and Liu (1992) propose stochastic frontier models in which the inefficiency effects (U_i) are expressed as an explicit function of a vector of firm specific variables and a random error. The single stage model proposed below is a straightforward extension of Kumbhakar, Ghosh and McGukin (1991) and Huang and Liu (1992) specifications utilising the γ paramaterisation from Battese and Corra (1977) described earlier. This approach is based on the previously defined general stochastic frontier production function defined in (1). The composition of the U_i are now defined more specifically as,

(7) $U_i = \mathbf{z}_i\delta + W_i$

The V_i in the composed error term of (1) are random variables which are assumed to be iid. $N(0,\sigma_V^2)$, and independent of the U_i which are non-negative random variables which are assumed to account for the technical inefficiency in production; z_i and δ are as defined above in (6). The W_i are independently distributed random errors which follow a truncated normal distribution, $N(\mu,\sigma_w^2)$. Joining (1) and (7) in a single formulation yields the single-stage stochastic frontier production function,

(8) $Y_i = x_i\beta \exp\{(V_i - (\mathbf{z}_i\delta + W_i))\} \qquad i=1,\ldots,N.$

Just as in the two-stage approach, different functional forms for the general model (8), such as Cobb-Douglas and Translog frontiers can be employed. Since the Cobb-Douglas is a restricted form of the translog, the preferred choice of functional forms is based on statistical tests. Equation (7) models the inefficiency effects, the U_i associated with the technical inefficiency of production in terms of farm and managerial specific variables, the z_i and the stochastic error terms, the W_i.[10]

The z_i should include any variables that help explain why production observations fall short of their corresponding stochastic frontier production values, $\exp(x_i\beta + V_i)$. In our model, the random variables W_i could be negative if $\mathbf{z}_i\delta > 0$, (i.e. $W_i \geq -\mathbf{z}_i\delta$).[11] The distributions of the W_i are therefore truncations

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[9] This is rapidly going to change as a result of statistical software developments that enable estimation of models with a degree of convenience, unknown before.

[10] The likelihood function is presented in Battese and Coelli (1993) and is expressed in terms of the variance ratio as defined in equation (3).

[11] Our model differs from Reifschneider and Stevenson (1981) who assume that the non-negative W_i are random variables independently and identically distributed $N(0, \sigma_w^2)$ and have a half-normal, gamma or exponential distribution. The assumption that the W_i are independently distributed (i.e. random noise) for all $i = 1,2,\ldots N$, is a restrictive and simplifying condition and implies that the U_i's are independently distributed.

of the $N(\mu,\sigma_w^2)$ distribution which correspond to the non-negativity of the U_i. The truncation points of the W_i depend on the values of the $\mathbf{z}_i$ and on the unknown δ parameters. Thus the truncation points may vary for different observations on different firms.

The technical efficiency of production for the i^th^ firm is therefore an extension of (4) where $U_i = \mathbf{z}_i\delta - W_i$ such that,

$$(9) \qquad TE = exp(-U_i) = exp[-(\mathbf{z}_i\delta - W_i)] = exp(-\mathbf{z}_i\delta + W_i)$$

Few empirical investigations apply both the two-stage estimation procedure defined by (5) and (6) and the single-stage estimation procedure described by (8). This investigation investigates both methods and compares the results. In addition, nested functional specifications of the frontier are tested. The idea is to identify the best specification for shrimp aquaculture technology. Both the theoretical and empirical investigation of shrimp farm efficiency is based on methods employed to analyse cross sectional data.

The general stochastic frontier model has been extended to consider panel data and time-varying technical efficiencies. In addition, the methodology has been applied to cost functions and also to the estimation of systems of equations. However, as this primary shrimp farm data set is *cross sectional*, the other applications are not discussed and detailed discussion of these can be found elsewhere.[12]

5.5 Frontier Selection & Tests of Hypotheses

It is of interest to (i) test which model specification of the frontier (Translog, Cobb-Douglas or OLS) best estimates the parameters in both the two-stage and single stage estimation procedures, and (ii) test hypotheses regarding the distribution of the random variables associated with the existence of technical inefficiency and residual error. In the first case, well-known statistical selection criteria are used to determine the most suitable specification of the production frontier model. The second part is to determine whether technical inefficiency does exist amongst shrimp farms in the sample. Finally, in the case of single-stage estimation only, we test whether the variables in the inefficiency effects model (see equation (9)) have any significant effect on the level of technical inefficiency. The statistically selected model- regardless of whether the two-stage or single-stage method is employed-provides the preferred estimates of the β_i and of technical efficiency (if technical inefficiencies among sample farms are determined to exist). The flow diagram in Figure 5.1 traces the method used.

In this analysis the nested stochastic Cobb-Douglas frontier is specified and tested even when the more general flexible Translog production function is initially found to be an acceptable specification. Thus, there is a slight deviation from the pure "general to specific" investigative methodology popularised by David Hendry (see Gilbert, 1986 for a detailed account of Hendry's methodology) for several reasons: First, to underscore the possible ramifications of incorrectly identifying a reduced model (i.e. the Cobb-Douglas model) as the preferred specification. Several seminal empirical studies (see Section 5.1: Overview of the Literature) specify and draw policy conclusions based on the inefficiency measures of the Cobb-Douglas model. These studies do not go on to specify the Translog frontier and use statistical tests to select the preferred model. As a result, policy recommendations are drawn from analysis of estimated technical efficiency measures from perhaps a second best model.[13] Second, this approach is used to underscore the strength of this method over other techniques. By using this method in model estimation and selection, a flexible and well specified stochastic model that yields efficient estimates and the preferred technical efficiency measures is ultimately chosen.

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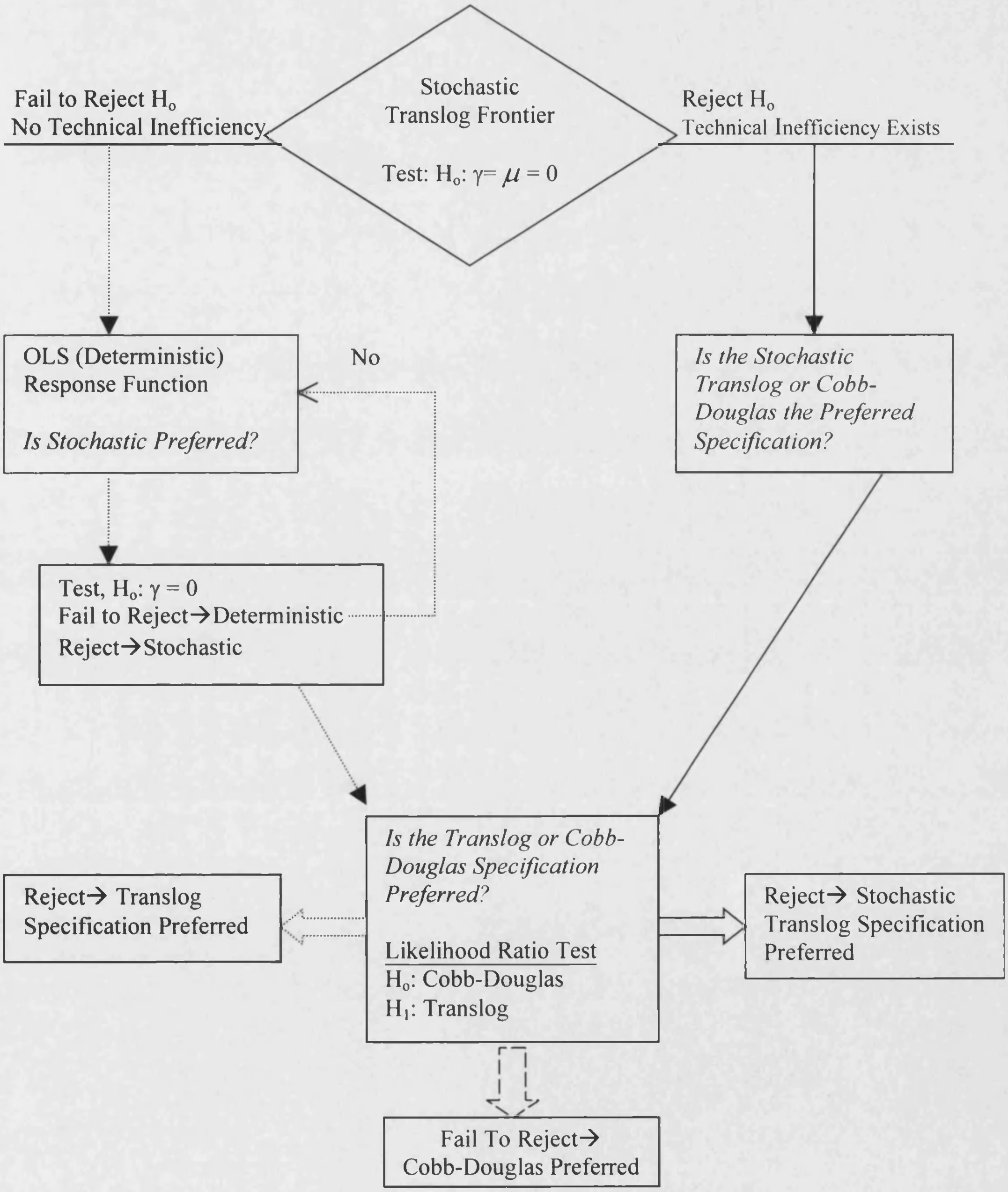
[12] A comprehensive review of this literature is available in Forsund, Lovell and Schmidt (1980), Schmidt (1986), Bauer (1990) and Greene (1993). For recent applications to panel data, see Piesse (1998), Thirtle et al. (1996) and Batesse and Coelli (1995).

[13] Some early examples include Kalirajan (1981), Battese and Corra (1977).

Figure 5.1: Flow Diagram



5.5.1 Selecting the Appropriate Frontier

First, the specification of the general and flexible Translog stochastic frontier production function is tested for both FPF approaches. The stochastic frontier production function is equivalent to the traditional response function (OLS) if the parameters γ and μ in (3) and (1), respectively are simultaneously equal to zero. If we fail to reject the null hypothesis, H_o: $\gamma = \mu = 0$, then it is possible to conclude that the given frontier is not significantly different from the traditional response function (OLS) for the shrimp farming sector and that technical inefficiency is not evident for the sample farmers (i.e. the U_i are not present in the model). However, the question remains, is the Translog specification of the frontier more suitable than the Cobb-Douglas specification? The Likelihood Ratio (LR) test (see 5.5.3) provides the method to chose between model specifications.

Second, it is important to test the significance of the γ parameter (i.e. by testing H_o: $\gamma = 0$) to see if any form of the stochastic frontier production function is required at all. If the null is rejected, then the frontier is said to be stochastic. However, this test is a weaker version of H_o: $\gamma = \mu = 0$ and is only used if we fail to reject this more powerful hypothesis.[14]

The opposite side of the flow diagram in Figure 5.1 suggests that if the null hypothesis (H_o: $\gamma = \mu = 0$) is rejected, it is possible to conclude that (1) inefficiency does exist among the sample farms and (2) the stochastic frontier model involved in estimating the parameters is something other than the traditional response function. In the single-stage estimation technique defined by (8), rejection of H_o: $\gamma = \mu = 0$ suggests that the W_i are present in the model. Once again, the question remains, is the Translog more suitable than the Cobb-Douglas specification? The answer to this question is determined by specifying

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[14] There is one important caveat worth mentioning. Any likelihood ratio test statistic involving a null hypothesis which includes the restriction that $\gamma = 0$ is not distributed Chi-square because the restriction defines a point on the boundary of the parameter space (see Lee, 1993). In this case, the likelihood ratio statistic has been shown to have a mixed Chi-square distribution (see Coelli (1993) and Coelli (1994) for a more detailed theoretical exposition of the mixed chi-square distribution). We may, however, follow the literature due to a lack of a more appropriate methodology and use the LR test while assuming a Chi-square distribution as an approximation for the mixed chi-square distribution.

the nested version of the stochastic Translog (i.e. the stochastic Cobb-Douglas) and employing the LR test to determine which specification is ultimately preferred.

5.5.2 Specifying the distribution of the errors

Once the preferred frontier is determined, the next task is to specify the distribution of the residuals (the inefficiency effects). The hypothesis that the inefficiency effects arise from the truncation of a half-normal distribution is tested by comparing the null hypothesis, H_o: $\mu = 0$ against its alternative. If we fail to reject this restriction, then it is possible to conclude that the U_i are distributed $|N(0, \sigma_U^2)|$, the half-normal distribution. If this restriction is rejected, then it is possible to conclude that the inefficiency effects may have a distribution other than half-normal (i.e. the U_i are distributed $N(\mu, \sigma_U^2)$), a distinction which implies that some farms may be plagued with severe technical inefficiency (Battese and Coelli, 1993). This study also explores the distribution of the inefficiency effects.

5.5.3 Model Selection

Generalised Likelihood Ratio tests are conducted to chose the preferred frontier specification. The Likelihood Ratio (LR) has a Chi-squared distribution and is defined by,

$$(10) \qquad LR = N \ln(\sigma_r^2 / \sigma_u^2) \sim \chi^2(q)$$

where σ_r^2 is the variance of the estimated restricted model; σ_u^2 is the variance of the estimated unrestricted model and N is the number of observations in the sample. The critical value is defined by $\chi^2(q)$, where q is the number of restrictions imposed. The null hypothesis is rejected in favour of the unrestricted model if $LR > \chi^2(q)$.

5.6 Data

Primary cross sectional data was collected from 82 shrimp farms located adjacent to Tikkavaram and Bestapalem, two coastal villages in Nellore District, Andhra Pradesh, India. Technical efficiency and its determinants are investigated using the models described earlier. These data were collected by the author and his assistants as a more specific component of a 530 shrimp farm survey conducted between November 1996 and March 1997 and are generally considered to be a good representative sample for statistical analysis (see Chapter 2). In addition to obtaining data on primary inputs used in brackishwater shrimp aquaculture production, this particular cross section also includes data on farm characteristics and managerial practices. These data enable investigation into the reasons why technical inefficiency may exist.

The data were collected for each of the 82 farm sample either at the farm itself or at the household of the farmer. Generally, larger farms had a paid manager who provided the necessary production figures at the farm itself where there was usually a records keeping office. Smaller farms tend to be operated by the owner who usually kept no written records. Data were collected from them based on their recollection.[15] Each of the 82 farmers provided information on five major production inputs and several farm characteristics.

In this analysis, shrimp production is assumed to be a function of five measurable inputs. *Land* is the total water spread area of the farm (in hectares); *Labour* is the total amount of family and hired labour inputs for all three stages of the production cycle (in person-days); *Seed* is the total number of seed inputs used per farm (in number of pieces); *Feed* is the amount of feed used per farm (in kilograms); *Aerators* are the number of aerators used per farm. Total production of shrimp per farm is measured in kilograms.

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[15] Chapter 2 discusses the possible bias in data collected from farmers' recollections.

Farm specific and managerial characteristics include the following:

- DLOC is a dummy variable that has a value of one if the farm is located adjacent to Tikkavaram village and zero if the farm is located adjacent to Bestapalem village;
- DSMF is a farm size dummy variable that has a value of one if the farm is less that 5 hectares in total area, zero otherwise;
- DEXT is a technology dummy variable that has a value of one if the farmer practices extensive culture (i.e. where the stocking density is below 60,000 seed per water spread hectare) and zero if more intensive stocking densities are used;
- DTRACT is a dummy variable that has a value of one if the farm manager/owner uses tractor inputs and zero, otherwise;
- DCHEM is a dummy variable which has a value of one if the farm manager uses chemical inputs such as lime and chlorine to keep the pond water clean and zero, otherwise;
- DFEED is a dummy variable that takes the value one if foreign feed input is used and zero if domestic feed is used;
- DCORP is a dummy variable that is given the value one if the farm is classified as a corporate or private limited farm and zero, otherwise;
- DOWN is a dummy variable that has the value one if the farm is owned by the operator or zero if leased;
- YRSOP is the number of years the farm has been in operation;
- WATEX is the percent of pond water exchanged daily;
- FEDTMS is the number of times per day that the shrimp fry are fed;
- AVPDSZ is the average size of a particular farm's shrimp ponds (in hectares);
- NOPNDS is the number of shrimp ponds operating on a particular farm.

The summary statistics are presented in Table 5.0.

Table 5.0
Summary Statistics for 82 Kandaleru Shrimp Farms

Variable	Units	Mean	S.D.	Min	Max
output, Y	kilograms	10936.70	26797.71	202.5	164500
land	hectares	8.37	17.61	0.6	150
labour	person-days	1234.14	1728.61	122.0	9846
seed	number	1556793.00	5408663.00	15000.0	4500000000
feed	kilograms	75115.41	269411.00	120.0	2137500
aerators	number	34.84	78.51	0.0	450
DLOC	-	0.426	0.497	0	1
DSMF	-	0.475	0.502	0	1
DEXT	-	0.597	0.493	0	1
DTRACT	-	0.902	0.298	0	1
DCHEM	-	0.390	0.490	0	1
DFEED	-	0.707	0.457	0	1
DCORP	-	0.183	0.388	0	1
DOWN	-	0.207	0.407	0	1
YRSOP	number	2.829	1.293	1	6
WATEX	percentage	6.806	4.691	0	20
FEDTMS	number	2.975	1.285	2	8
AVPNDZ	hectares	0.665	0.200	0.33	1.215
NOPNDS	number	11.817	18.972	1	150

A unique characteristic of these data, well worth noting is that it corresponds to the second crop cycle for the 1996 year, which was the first bumper harvest experienced by this region. Previous years had seen widespread crop failure throughout the Kandaleru shrimp farming region as a result of disease attributed to environmental pollution and diseased seed. Therefore the results obtained from this analysis can be assumed as an example of a "best case" situation to date. Of the 82 shrimp farms surveyed, three farms revealed that they were forced to harvest early as a result of a recurring disease problem affecting the crop. Nonetheless, these farms were included in the sample in order to compare their level of inefficiency with the other sample farms.[16]

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[16] For a detailed discussion on the survey methodology and on the potential bias of the data, see Chapter 2.

5.7 Model Specification, Estimation & Results

Two specifications of the general stochastic production frontier model, namely, the Translog and Cobb-Douglas specifications are proposed. Many earlier studies restricted their specification to Cobb-Douglas only. However, the Cobb-Douglas specification imposes severe *a priori* restrictions on farm technology by retracting the elasticities of input substitution to one and production elasticities to be constant. Flexible functional forms, such as the translog function are not restricted in this way.

The stochastic translog model with symmetry imposed is generally specified as follows,

$$(11) \qquad \ln(y_i) = \beta_o + \sum_{k=1}^{5} \beta_k \ln x_{ki} + \frac{1}{2}\sum_{k=1}^{5}\sum_{j=1}^{5} \beta_{kj} \ln x_{ki} \ln x_{ji} + e_i$$

where *ln* denotes natural logarithms, *k and j* index the five inputs and *i* indexes each of the 82 farms. *y* is the output for each farm in the sample; x_{ki} represents input *k* for farm i; x_{ji} represents input *j* for farm i; β_0 and β_{kj} are unknown parameters. The stochastic error, *e*, is defined as $e = V + U$ where $U \geq 0$ and represents the inefficiency effects. *V* is a random error. The equality of β_{kj} and β_{jk} for $k \neq j$ is assumed throughout which implies that this specification has imposed symmetry.[17] The stochastic Cobb-Douglas frontier is a nested version of the translog where all $\beta_{kj} = 0$.

5.7.1 Two-Stage Estimation Procedure

Stage One

Given the variables specific to the shrimp farming sector, the specification of the stochastic Translog frontier with imposed symmetry can be defined as,

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[17] Stating that $\beta_{kj} = \beta_{jk}$ is necessary to maintain consistency with Young's theorem which says that the second cross partial derivative of the function with respect to *k*, then *j*, is equal to the second cross partial with respect to *j*, then *k* (Berndt and Christiansen, 1973).

$$(12)\quad \ln(Y_i) = \beta_0 + \beta_1\ln(\mathrm{Land}_i) + \beta_2\ln(\mathrm{Labor}_i) + \beta_3\ln(\mathrm{Seed}_i) + \beta_4\ln(\mathrm{Feed}\ ) + \beta_5\ln(\mathrm{Aerators}_i) + \beta_6\ \ln(\mathrm{Land}_i)^2 + \beta_7\ln(\mathrm{Labor}_i)^2 + \beta_8\ln(\mathrm{Seed}_i)^2 + \beta_9\ln(\mathrm{Feed}_i)^2 + \beta_{10}\ln(\mathrm{Aerators}_i)^2 + \beta_{11}\ln(\mathrm{Land}_i)\ln(\mathrm{Labour}_i) + \beta_{12}\ln(\mathrm{Land}_i)\ln(\mathrm{Seed}_i) + \beta_{13}\ln(\mathrm{Land}_i)\ln(\mathrm{Feed}_i) + \beta_{14}\ln(\mathrm{Land}_i)\ln(\mathrm{Aerators}_i) + \beta_{15}\ln(\mathrm{Labour}_i)\ln(\mathrm{Seed}_i) + \beta_{16}\ln(\mathrm{Labour}_i)\ln(\mathrm{Feed}_i) + \beta_{17}\ln(\mathrm{Labour}_i)\ln(\mathrm{Aerators}_i) + \beta_{18}\ln(\mathrm{Seed}_i)\ln(\mathrm{Feed}_i) + \beta_{19}\ln(\mathrm{Seed}_i)\ln(\mathrm{Aerators}_i) + \beta_{20}\ln(\mathrm{Feed}_i)\ln(\mathrm{Aerators}_i) + (V_i + U_i)\ ,$$

where *i* indexes each of the 82 sample shrimp farms. All other variables are as previously defined. The data specific stochastic Cobb-Douglas frontier model estimated is simply a nested version of (12) with the squared terms and cross product terms eliminated from the model (i.e. β_6, $\beta_7,\ldots,\beta_{20} = 0$).

By estimating each specification and conducting model selection tests (see flowchart, Figure 5.1), it is possible to determine which specification is preferred, and thus which technical efficiency measures to use in the second modelling stage. The maximum-likelihood estimates of parameters for each stochastic frontier model outlined above are obtained using the *Frontier 4.1* computer software package (Coelli, 1994) and are presented in Table 5.1 below.

Table 5.1
Maximum Likelihood Estimates for Parameters
of Two Selected Stochastic Frontiers

		Cobb-Douglas		Translog	
variable		*coefficient*	*t-statistic*	*coefficient*	*t-statistic*
Constant	β_0	-2.3874	-1.7302	-79.0227	-85.1648
ln(land)	β_1	0.1374	0.7353	-18.6139	-22.5784
ln(labour)	β_2	0.1033	1.0362	7.6015	8.5968
ln(seed)	β_3	0.7606	4.5243	18.2383	51.7502
ln(feed)	β_4	0.0199	0.2078	-9.7514	-37.9685
ln(aerators)	β_5	-0.0016	-0.0483	-1.8263	-2.1139
$\ln(\text{land})^2$	β_6			-0.8351	-4.3759
$\ln(\text{labour})^2$	β_7			-0.2888	-0.6468
$\ln(\text{seed})^2$	β_8			-1.0549	-5.8835
$\ln(\text{feed})^2$	β_9			-0.2167	-0.7091
$\ln(\text{aerators})^2$	β_{10}			0.0078	0.3773
ln(land) * ln(labour)	β_{11}			1.5660	3.1256
ln(land) * ln(seed)	β_{12}			1.9559	10.5766
ln(land) * ln(feed)	β_{13}			-1.5498	-4.3597
ln(land) * ln(aerat)	β_{14}			-0.2305	-1.5587
ln(labour) * ln(seed)	β_{15}			-0.6113	-1.2068
ln(labour) * ln(feed)	β_{16}			0.2150	0.7623
ln(labour) * ln(aerat)	β_{17}			-0.0335	-0.2337
ln(seed) * ln(feed)	β_{18}			1.1373	2.4786
ln(seed) * ln(aerat)	β_{19}			0.1727	1.2142
ln(feed) * ln(aerat)	β_{20}			0.0240	0.2933
mu		-1.44	-1.3137	0.04341	0.1577
sigma-squared		0.5839	1.8886	0.17524	13.1379
gamma		0.8916	10.1443	0.98328	7.4834
Loglikelihood		-29.36		-7.06	
Chi2 Statistic		2.09		11.79	
Average TE		0.788		0.719	
Number of Iterations		21		56	
Degrees of Freedom		76		61	
Note: The t-value and cut-off point for H_0 is 2.39 at one percent, 2.0 at five percent, and 1.67 at ten percent.					

5.7.2 *Model Selection*

Following the general to specific hypothesis testing procedure described in the flow diagram (Figure 5.1), the analysis in this sub-section concludes that the stochastic Translog frontier is found to be the preferred specification of the production frontier. Moreover, tests on the inefficiency effects suggest that there may be severe technical inefficiency amongst sample shrimp farms. Finally, we demonstrate how an inappropriate specification of the frontier could inadvertently be supported if a more specific to general methodology were adopted.

The analysis begins by testing whether the general and flexible stochastic Translog frontier production function with imposed symmetry can be statistically differentiated from the traditional response function (i.e. to determine whether there is any need to specify a model with a stochastic frontier). Table 5.2 illustrates that the null hypotheses (H_o: $\gamma = \mu = 0$) is rejected for the stochastic Translog specification since the Chi-square test statistic (11.79) exceeds the critical value (5.99). This suggests that (i) the stochastic Translog frontier model is preferred to the traditional response function, and (ii) inefficiency does exist amongst shrimp farms in the sample. Moreover, the fact that the inefficiency effect has a distribution other than $N(0,\sigma_u^2)$ suggests that there may be severe technical inefficiency amongst our sample farmers.

Next, we demonstrate how an inappropriate specification of the frontier could inadvertently be supported if a more specific to general methodology were adopted. The stochastic Translog function is trimmed to its more restrictive (nested) Cobb-Douglas specification. This specification fails to reject the null hypothesis (H_o: $\gamma = \mu = 0$) since the Chi-squared critical value (5.99) exceeds the test statistic (2.09) in the Cobb-Douglas model. This result suggests that this stochastic Cobb-Douglas specification is not significantly different from the traditional response function and that technical inefficiency is not evident in the sample farms.

Given that the U_i may be normally distributed, the following restriction, $\mu = 0$ is applied to the specification of the Cobb-Douglas model. The model is then re-estimated. Next, we test the null hypothesis, H_o: $\gamma = 0$. This hypothesis suggests that the parameters are best estimated using the traditional response function. Once again, the Cobb-Douglas specification fails to reject the null hypothesis. This reaffirms that the Cobb-Douglas model is not significantly different from the traditional response function.

Table 5.2
Tests of Hypotheses for Parameters of the Distribution of the Farm Effects, U_i, Associated with the Stochastic Production Function for 82 Kandaleru Shrimp Farms

Null Hypotheses	Loglikelihood	χ^2 – *test statistic*	Decision
H_o: $\gamma = \mu = 0$		χ^2 (2, 0.95) = 5.99*	
Translog	-7.06	*11.79*	Reject H_o
Cobb-Douglas	-29.36	*2.09*	Accept H_o
Given that $\mu = 0$; --------------------		χ^2 (1, 0.95) = 3.84*	
H_o: $\gamma = 0$			
Cobb-Douglas	-30.22	*0.38*	Accept H_o

Note: *Chi-squared critical values

The conclusion that the data is best estimated by the traditional response function and that there is no technical inefficiency amongst the sample farms would be supported had the investigation been discontinued after testing the Cobb-Douglas specification only. However, this conclusion is clearly false and suggests the appropriateness of using Hendry (1983) general to specific model selection approach. For completeness, a model selection LR test is conducted to determine which of the two specifications is preferred (see Table 5.3). The nested Cobb-Douglas specification is rejected in favour of the stochastic Translog frontier as the likelihood ratio statistic (98.6) exceeds the Chi-square critical value (22.4).

Table 5.3
Likelihood Ratio Tests for Model Selection

Null Hypotheses	Likelihood Ratio Statistic	χ^2 critical value	Decision
H_o: Cobb-Douglas H_1: Translog	98.6	χ^2 (13, 0.95) = 22.36	Reject H_o

Distribution of Technical Inefficiency

The above result suggests that the parameter estimates and technical efficiency measures from the estimation of the stochastic Translog production frontier model (13) are preferred to those obtained by the (nested) Cobb-Douglas specification. The efficiency measures derived from the stochastic Translog specification are therefore used to examine the determinants of technical inefficiency in the second stage model. First, however, the distribution of technical efficiency measures for the sample shrimp farms are discussed.

Table 5.4 presents the distribution of technical efficiency among sample Kandaleru shrimp farms. Figure 5.3 presents a histogram of the frequency distribution of each shrimp farming unit in the sample. The minimum estimated efficiency is approximately 22 percent, the maximum is 99 percent and the mean is approximately 72 percent.

Table 5.4
The Distribution of Farm Specific Technical Efficiency Measures Obtained from the Stochastic Translog Production Frontier

Efficiency Index	Number of Shrimp Farms	Percentage of Farms
100 to 95.01	6	7.3
95 to 90.01	8	9.8
90 to 85.01	7	8.5
85 to 80.01	10	12.2
80 to 75.01	9	11.0
75 to 70.01	9	11.0
70 to 65.01	6	7.3
65 to 60.01	6	7.3
60 to 55.01	13	15.9
55 to 50.01	4	4.9
50 to 45.01	2	2.4
45 to 40.01	0	0.0
40 to 35.01	1	1.2
35 to 30.01	0	0.0
30 to 25.01	1	1.2
25 to 20.01	1	1.2
under 20	0	0.0

N=82; Mean TE = 0.719

The Determinants of Technical Efficiency

Second Stage

With a given technology to transform physical inputs into outputs the technical efficiency of farmers in a given sample can vary significantly. Some farmers are able to achieve a high degree of technical efficiency while others are considered technically inefficient. The question remains, why? The large distribution of the technical efficiency indices of shrimp farms suggest that efficient farms may have more adequate technical knowledge than less efficient farms. On the other hand, the variance of technical efficiency measures in the sample may be attributable to other factors such as socio-economic and demographic factors as suggested by Timmer (1971), Muller (1974) and Kalirajan and Shand (1989) in agriculture based studies. The possible reasons for the significant distribution of inefficiency amongst Kandaleru shrimp farms is explored by modelling and estimated a model for the inefficiency effects.

The second-stage investigation postulates the following relationship for the general inefficiency model of equation (6),

$$\text{TE}_i = \delta_0 + \delta_1 \text{DLOC}_i + \delta_2 \text{DSMF}_i + \delta_3 \text{DEXT}_i + \delta_4 \text{DTRACT}_i + \delta_5 \text{DCHEM}_i + \delta_6 \text{DFEED}_i + \delta_7 \text{DCORP}_i + \delta_8 \text{DOWN}_i + \delta_9 \text{YRSOP}_i + \delta_{10} \text{WATEX}_i + \delta_{11} \text{FEDTMS}_i + \delta_{12} \text{AVPDSZ}_i + \delta_{13} \text{NOPNDS}_i + W_i \tag{14}$$

where, TE_i = technical efficiency index of the i^th^ farm derived from estimation of the stochastic Translog specification and W_i is a random error assumed to be iid. $N(0,\sigma_w^2)$.

The estimated parameters, t-ratios and other important statistics for (14) are presented in the first column of Table 5.5. Specification 1 yields only one coefficient that is statistically significant at 10 percent or less (i.e. dtract). Although the R-squared value is reasonable for the second stage regression at 0.1330, the adjusted R-square statistic-which takes into account degrees of freedom-is not sensible at -0.0328. The model (14) is therefore reduced by imposing zero restrictions on parameters with low t-ratios.[18] This yields Specification 2 and the more preferred Specification 3 (see table 4.5).

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[18] We follow an entirely *ad hoc* general to specific modelling approach, eliminating variables with low t-ratios in order to define a parsimonious and meaningful efficiency model.

Specification 3 yields an R-squared of 0.113 and an adjusted R-squared of 0.067 implying that this specification of the inefficiency model is sensible.[19]

The OLS regression result for Specification 3 indicates that location, the use of a tractor during pond preparation and that chemical use are significant influences in explaining technical efficiency amongst Kandaleru shrimp farms. The positive coefficient on the *dtract* dummy suggests that farms that use tractor inputs have higher efficiency levels. The negative coefficient on *dchem* suggests that farms using chemical inputs to keep the pond water clean are less efficient. This is a particularly perplexing result but not without explanation. Chemical inputs are not included as a primary input in our stochastic frontier model. Instead, the dummy variable is used to help explain inefficiencies in the second stage. Including the level of chemical inputs in the model would increase the number of total inputs and most likely decrease the estimated inefficiency measure. Including this variable in the second stage therefore illustrates the trade-off between efficiency and expected yield.

Particularly noteworthy is the result that the number of years the farm has been in operation is not statistically significant. This suggests that there is equal advantage for all farmers regardless of managerial experience. In addition, the farm size dummy, *dsmf* and technology dummy *dext* are not significant in the unrestricted model. This result suggests that small farms fare no better nor worse in terms of their efficiency than larger farms and generally, farms using more intensive methods of production are no more efficient than farms using less intensive farming practices.

The positive and significant coefficient on the *dloc* dummy suggests that farm location plays an important role in explaining technical efficiency. Tikkavaram farms are found to be more efficient than those located in Bestapalem. This is an important finding as it suggests that production environment is an important factor in explaining the variation of technical efficiency in shrimp farm production. We discuss these results in greater detail in the final section of this chapter.

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[19] Low R-squared and adjusted-R-squared measures are not unusual for the second stage regression (see Parikh and Shah, 1994; Kalirajan and Shand, 1989 for other examples).

Table 5.5
Second Stage Regression Results Explaining Technical Efficiency

	Specification 1		Specification 2		Specification 3	
	coefficient	*t-stat*	*coefficient*	*t-stat*	*coefficient*	*t-stat*
const.	.5188203	1.258	0.547715	7.988	0.546647	8.006
DLOC	.0589479	1.258	0.070467	1.812	0.067309	1.752
DSMF	.0156292	0.258				
DEXT	.0588416	0.508				
DTRACT	.1540552	2.076	0.145353	2.198	0.143312	2.178
DCHEM	-.0120886	-0.106	-0.054866	-1.229	-0.064838	-1.558
DFEED	.0487705	1.044	0.051837	1.216		
DCORP	-.0074173	-0.096				
DOWN	-.0319447	-0.525				
YRSOP	-.0097969	-0.574				
WATEX	.0006887	0.102				
FEDTMS	.0125437	0.495				
AVPDSZ	-.053448	-0.479				
NOPNDS	-.0008225	-0.613	0.547715	-0.635		
F =		0.80		2.03		2.45
Prob > F		0.655		0.084		0.053
R^2		0.133		0.118		0.113
Adj R^2		-0.328		0.060		0.067

Note: All non-dummy variables are in levels; a blank cell marks variables that were excluded from the specification of the inefficiency model.

5.8 The Single-Stage Estimation Procedure

5.8.1 The Model

Two specifications for the general stochastic production frontier model (8) examined in this section are the Cobb-Douglas and Translog with imposed symmetry. Just as in the first stage of the two-stage estimation procedure, each stochastic specification is estimated and several model selection tests are conducted to determine which frontier specification is preferred. However, unlike in the two-stage approach, the single-stage approach estimates the *beta* and *delta* parameters and predicts the technical efficiency measures simultaneously in one stage. For each of the specifications of (8), the inefficiency effects are modelled as,

$$(15) \quad U_i = \delta_0 + \delta_1 DLOC_i + \delta_2 DSMF_i + \delta_3 DEXT_i + \delta_4 DTRACT_i + \delta_5 DCHEM_i + \delta_6 DFEED_i + \delta_7 DCORP_i + \delta_8 DOWN_i + \delta_9 YRSOP_i + \delta_{10} WATEX_i + \delta_{11} FEDTMS_i + \delta_{12} AVPDSZ_i + \delta_{13} NOPNDS_i + W_i$$

All variables are as previously defined. The stochastic frontier production function defined in (8) and (15) is estimated using the maximum likelihood procedure in the computer software package, *Frontier 4.1* (Coelli, 1994). Table 5.6 summarises the estimations of the stochastic Cobb-Douglas and Translog specifications.

Table 5.6

Single-Stage Maximum Likelihood Estimates for Parameters of Two Selected Stochastic Frontier Models

		Cobb-Douglas		Translog	
variable	param	*coefficient*	*t-statistic*	*coefficient*	*t-statistic*
Constant	β_0	-2.074	-1.78	-78.53	-78.40
ln(land)	β_1	0.353	1.89	-14.42	-5.90
ln(labour)	β_2	-0.013	-0.13	-1.41	-0.74
ln(seed)	β_3	0.719	4.69	21.60	16.10
ln(feed)	β_4	0.085	0.84	-9.34	-7.91
ln(aerators)	β_5	0.004	0.14	-0.58	-0.60
$\ln(\text{land})^2$	β_6			0.29	0.74
$\ln(\text{labour})^2$	β_7			0.01	0.61
$\ln(\text{seed})^2$	β_8			-0.13	-9.42
$\ln(\text{feed})^2$	β_9			-0.29	-2.41
$\ln(\text{aerators})^2$	β_{10}			-0.01	-0.34
ln(land) * ln(labour)	β_{11}			-0.54	-0.10
ln(land) * ln(seed)	β_{12}			2.22	6.31
ln(land) * ln(feed)	β_{13}			-1.62	-5.85
ln(land) * ln(aerators)	β_{14}			0.01	0.01
ln(labour) * ln(seed)	β_{15}			-0.06	-0.21
ln(labour) * ln(feed)	β_{16}			0.29	1.57
ln(labour) * ln(aerators)	β_{17}			-0.09	-1.01
ln(seed) * ln(feed)	β_{18}			1.18	5.17
ln(seed) * ln(aerators)	β_{19}			0.06	0.53
ln(feed) * ln(aerators)	β_{20}			0.05	0.88
const	δ_0	0.23	0.27	1.28	0.95
DLOC	δ_1	0.29	1.31	0.42	1.62
DSMF	δ_2	-1.09	-1.99	-0.80	-1.35
DEXT	δ_3	-0.64	-1.02	-2.20	-2.73
DTRACT	δ_4	-1.11	-1.59	-3.67	-4.03
DCHEM	δ_5	0.47	0.89	-0.11	-0.19
DFEED	δ_6	-0.06	-0.27	-0.05	-0.16
DCORP	δ_7	0.18	0.44	-0.42	-0.96
DOWN	δ_8	0.14	0.52	-0.33	-0.73
YRSOP	δ_9	0.05	0.68	0.08	0.86
WATEX	δ_{10}	-0.02	-0.97	-0.02	-0.56
FEDTMS	δ_{11}	-0.18	-1.92	0.22	1.73
AVPDSZ	δ_{12}	1.56	2.68	1.39	1.98
NOPDS	δ_{13}	0.02	3.38	0.05	4.70
sigma-squared		.140332		.273503	
Loglikelihood		-13.593		9.647	
Chi2 Statistic		33.63		45.21	
Mean TE		0.847		0.759	
Degrees of Freedom		76		61	

Note: The t-value and cut-off point for H_0 is 2.39 at one percent, 2.0 at five percent, and 1.67 at ten percent.

5.8.2 Model Selection

Following the "general to specific" model estimation and selection procedure discussed in Section 5.5 and outlined in figure 5.1, the first step is to determine whether the Translog specification of the stochastic frontier model (8) best describes the data. The stochastic Translog frontier production function is first tested against the traditional response function (OLS) with the following null hypothesis, H_o: $\gamma = \mu = 0$. Moreover, this test determines whether there is any need to specify a stochastic frontier model at all. The null hypothesis is rejected for the stochastic Translog specifications since the value of the test statistic (45.21) is greater than the Chi-squared critical value (5.99). This result suggests that the stochastic Translog frontier is significantly different from the traditional response function and that technical inefficiency is evident amongst the sample farms in the data set (see Table 5.7).

For completeness, the stochastic Cobb-Douglas frontier is specified and tested. The null hypothesis (H_o: $\gamma = \mu = 0$) is rejected suggesting that the stochastic Cobb-Douglas specification is preferred over the traditional response function, OLS. The question remains, which specification is preferred, the stochastic Translog or the more restrictive Cobb-Doulas frontier? As the Cobb-Douglas is a nested specification of the Translog model, it is possible to identify which specification is preferred by conducting a likelihood ratio test between the two specifications. The LR test suggests that the stochastic Translog frontier model is preferred to the nested stochastic Cobb-Douglas specification since the likelihood ratio (54.71) exceeds the Chi-squared critical value (24.99). The Cobb-Douglas specification is thus rejected in favour of the stochastic Translog production function (see Table 5.8).

Table 5.7

Tests of Hypotheses for Parameters of the Distribution of the Farm Effects, U_i, Associated with the Stochastic Production Function for Kandaleru Shrimp Farms

Null Hypotheses	Loglikelihood	χ^2 – *test statistic*	Decision
$H_0: \gamma = \mu = 0$		χ^2 (2, 0.95) = 5.99*	
Translog	9.65	*45.21*	Reject H_0
Cobb-Douglas	-13.59	*33.63*	Reject H_0

Note: *Chi-squared critical value

Table 5.8

Likelihood Ratio Tests for Model Selection

Null Hypotheses	Likelihood Ratio	χ^2 –critical value	Decision
H_0: Cobb-Douglas H_1: Translog	54.72	χ^2 (15, 0.95) = 24.99	Reject H_0

The Translog model is found to be the preferred statistical specification. Next, the joint explanatory power of the z_i variables in the stochastic Translog specification of (15) is examined. This is to determine whether the variables included in the inefficiency effects model have any significant effect on the level of technical inefficiency. The null hypothesis that the inefficiency effects are not a linear function of farm specific characteristics and managerial characteristics ($H_0: \delta_i = 0$; i=1,2,..13) is rejected (see Table 5.9). This indicates that the joint effect of these thirteen explanatory variables on the level of technical inefficiency is significant, although the individual effects of one or more of the variables may not be statistically significant. Thus the inclusion of the inefficiency model in the specification of the single-stage model is justified.

Table 5.9
Chi-squared Test of the Inefficiency Effects

Null Hypotheses	χ^2 –statistics	Decision
Assuming Stochastic Translog:	χ^2 (13, 0.95) = 22.36*	
H$_o$: $\delta_i = 0$; i=1,2,..11	*45.21*	Reject H$_o$

Note: *denotes the Chi-squared critical value

The parameters *gamma* and *sigma* squared are associated with the random variables V_i and W_i. Generalised likelihood-ratio tests of the hypotheses that the random errors in the inefficiency model are absent (i.e. $\mu \neq 0$) or that they arise from the half-normal distribution (i.e. μ=0) are tested. The null hypotheses that the inefficiency effects have no random components (that is, the W_i are not present in the model or H$_o$:$\gamma = \mu$=0) is rejected. Additionally, the hypothesis that the inefficiency effects arise from the truncation of a half-normal distribution (H$_o$: μ = 0) is also rejected.

This result would not have been expected had the farm specific and managerial variables (i.e. the z variables) explained the inefficiency effects adequately. It is possible to conclude, however, that there are other important farm specific and managerial characteristics missing from the inefficiency model, that if included, would theoretically allow us to "accept" the hypothesis that the inefficiency effects arise from the truncation of the half-normal distribution. However, this also implies the existence of omitted variables which could bias the *beta* and *delta* estimates.

5.8.3 The Preferred Model

The stochastic Translog production function is known to exhibit problems of multicollinearity as a result of the additional squared and cross product terms included as explanatory variables. One potential solution to multicollinearity is to selectively remove those squared or cross product terms whose t-ratios are below a certain critical value (Boisvert, 1992:30). This strategy has been successfully employed in Shih, Hushak and Rask (1977). The key is to remove unnecessary explanatory variables without destroying the flexibility in the relationships of the inputs, which remains the strength of this model. Several parameter estimates of the stochastic Translog function and inefficiency model (13) estimated above are far from significant (i.e. the asymptotic t-ratios are less than 1.3). Following Boisvert (1992) the trimming process begins by removing these statistically insignificant explanatory variables.[20]

In Table 5.10 the parameter estimates, asymptotic t-ratios and other significant statistics are presented for the stochastic Translog frontier model in its original form and for two reduced frontier models, called Model 1 and Model 2. Model 1 omits explanatory variables with low t-ratios, but leaves the inefficiency model untouched. Model 2 is a nested version of Model 1 with the explanatory variables with low t-ratios in the inefficiency model removed.

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[20] The same method was used to trim the Translog model presented using the two-stage approach discussed earlier. However, since statistical tests suggested that the efficiency indices estimated by the full and reduced models were not significantly different from each other, the results were not presented. In addition, *a priori* knowledge suggests that the single-stage model yields efficient *beta* estimates and these estimates are therefore the preferred technical efficiency measures. For this reason only the results of the single-stage estimation procedure are discussed in the final assessment of shrimp farm efficiency and overall technical performance of the sector.

Table 5.10
Single-Stage Maximum Likelihood Estimates for Parameters of Three Selected Inefficiency Stochastic Frontiers

		Translog Frontier Model 0		Trimmed Translog Model 1		Trimmed Translog Model 2	
variable		*coefficient*	*t-statistic*	*coefficient*	*t-statistic*	*coefficient*	*t-statistic*
Constant	β_0	-78.53	-78.40	-83.38	-61.21	-83.14	-64.48
ln(land)	β_1	-14.42	-5.90	-15.99	-8.71	-15.36	-9.68
ln(labour)	β_2	-1.41	-0.74	-1.59	-2.24	-1.35	-2.56
ln(seed)	β_3	21.60	16.10	23.24	22.40	23.26	23.21
ln(feed)	β_4	-9.34	-7.91	-10.50	-6.87	-10.85	-6.90
ln(aerators)	β_5	-0.58	-0.60	0.31	1.25	0.29	1.11
$\ln(\text{land})^2$	β_6	0.29	0.74				
$\ln(\text{labour})^2$	β_7	0.01	0.61				
$\ln(\text{seed})^2$	β_8	-0.13	-9.42	-1.47	-12.31	-1.49	-12.13
$\ln(\text{feed})^2$	β_9	-0.29	-2.41	-0.33	-2.87	-0.37	-2.92
$\ln(\text{aerators})^2$	β_{10}	-0.01	-0.34				
ln(land) * ln(labour)	β_{11}	-0.54	-0.10				
ln(land) * ln(seed)	β_{12}	2.22	6.31	2.25	7.43	2.16	8.82
ln(land) * ln(feed)	β_{13}	-1.62	-5.85	-1.42	-4.99	-1.36	-5.78
ln(land) * ln(aerators)	β_{14}	0.01	0.01				
ln(labour) * ln(seed)	β_{15}	-0.06	-0.21				
ln(labour) * ln(feed)	β_{16}	0.29	1.57	0.21	2.12	0.18	2.37
ln(labour) * ln(aerators)	β_{17}	-0.09	-1.01	-0.05	-1.26	-0.05	-1.14
ln(seed) * ln(feed)	β_{18}	1.18	5.17	1.35	5.18	1.42	5.25
ln(seed) * ln(aerators)	β_{19}	0.06	0.53				
ln(feed) * ln(aerators)	β_{20}	0.05	0.88				
const	δ_0	1.28	0.95	1.60	0.95	1.70	0.82
DLOC	δ_1	-0.42	-1.62	-0.22	-0.88	-0.33	-1.58
DSMF	δ_2	-0.80	-1.35	-1.07	-1.71	-1.34	-1.87
DEXT	δ_3	-2.20	-2.73	-2.16	-1.72	-1.92	-1.29
DTRACT	δ_4	-3.67	-4.03	-3.55	-2.42	-3.59	-1.91
DCHEM	δ_5	-0.11	-0.19	0.20	0.34	0.50	0.87
DFEED	δ_6	-0.05	-0.16	0.03	0.14		
DCORP	δ_7	-0.42	-0.96	-0.45	-0.82		
DOWN	δ_8	-0.33	-0.73	-0.10	-0.33		
YRSOP	δ_9	0.08	0.86	0.09	0.91	0.09	1.03
WATEX	δ_{10}	-0.02	-0.56	-0.04	-1.54	-0.04	-1.51
FEDTMS	δ_{11}	0.22	1.73	0.12	0.88		
AVPDSZ	δ_{12}	1.39	1.98	1.56	2.30	1.56	2.60
NOPDS	δ_{13}	0.05	4.70	0.05	5.11	0.50	5.38
sigma-sq		0.273	4.20	0.280	3.58	0.283	4.60
gamma		0.955	56.00	0.946	35.8	0.945	34.1
loglikelihood		9.647		5.44		5.01	
LR-Test Stat		45.21		50.38		49.50	

Note: The t-value and cut-off point for H_0 is 2.39 at one percent, 2.0 at five percent and 1.67 at ten percent.

Next, LR tests are employed (see Table 5.11) to test the unrestricted stochastic Translog production function (Model 0) against the reduced frontier models (Model 1 and Model 2).

Table 5.11

Likelihood Ratio Tests for Model Selection

Null Hypotheses	Likelihood Ratio	χ^2 –critical value	Decision
H_0: Model 1 H_1: Model 0	2.04	χ^2 (8, 0.95) = 14.06	Accept H_o
H_0: Model 2 H_1: Model 1	0.881	χ^2 (4, 0.95) = 7.80	Accept H_o

In the first likelihood ratio test between the unrestricted model 0 and restricted model 1, the null hypothesis (β_k=0; k=6,7,10,11,14,15,19,20) cannot be rejected. The preferred specification is therefore model 1. In the second LR test between model 1 and model 2, the restrictions imposed on model 1 (H_o: δ_i=0, i=6,7,8,11;β_k=0; k=6,7,10,11,14,15,19,20) cannot be rejected. The specification of model 2 is preferred to model 1 and thus preferred overall.

5.8.4 Discussion

The signs of the *beta* estimates are positive and statistically significant for *seed* and *aerators* and negative and statistically significant for *land, labour* and *feed* in the preferred model. The negative coefficient associated with the interaction between land and feed, and labour and aerators suggest that these interactions all negatively affect output, while the cross effects of land and seed, labour and feed, and seed and feed are positive and significant.

There are several well known problems associated with the use of Translog production function that make the interpretation of the results less than adequate for understanding the direct relationship between inputs and output. However, as this analysis is primarily concerned with measuring and explaining technical inefficiency amongst Kandaleru shrimp farms, there is little reason to be too concerned with the limitations of the stochastic Translog frontier model. The specification of the stochastic Translog function does not impede the prediction of technical efficiency, nor does it impede any rigorous analysis of the efficiency index and its distribution among the sample shrimp farms.

5.8.5 Distribution of Technical Efficiency

The mean predicted technical efficiency obtained for the 82 shrimp farms using the single-stage estimation technique from the preferred reduced model is 0.747. The predicted efficiency measures show considerable variability among shrimp farmers (see Table 5.12). A list of each farm's efficiency index is presented in Appendix 5A, Table 5A.1.

Table 5.12
Farm Specific Technical Efficiency Measures in the Stochastic Translog Production Frontier (Single-Stage Model 2)

Efficiency Index	Number of Shrimp Farms	Percentage of Farms
100 to 95.01	10	12.2
95 to 90.01	28	34.1
90 to 85.01	9	11.0
85 to 80.01	2	2.4
80 to 75.01	6	7.3
75 to 70.01	3	3.7
70 to 65.01	0	0.0
65 to 60.01	3	3.7
60 to 55.01	2	2.4
55 to 50.01	4	4.9
50 to 45.01	1	1.2
45 to 40.01	3	3.7
40 to 35.01	3	3.7
35 to 30.01	1	1.2
30 to 25.01	2	2.4
25 to 20.01	2	2.4
under 20	4	4.9

N=82; Mean TE = 0.747

5.8.6 Explaining Technical Inefficiency

The coefficients of the explanatory variables in the single-stage stochastic inefficiency model presented in Table 5.10 are of particular interest. Interpretation of the *delta* coefficients in the single-stage model are opposite to that of the two-stage method's results. This is a direct result of the construction of the error term in (8) which takes the difference between the random variable V_i and the inefficiency effect U_i. By contrast, the two-stage approach models the error term as the sum of the random variable V_i and the inefficiency effect U_i. A negative coefficient on *delta* therefore implies that the variable associated with that estimated parameter has efficiency enhancing characteristics (i.e. reduced inefficiency).

Following the single-stage results, the negative coefficient on the location dummy suggests that farms located in Tikkavaram are more efficient than their downstream neighbours. The negative coefficient on small farm size dummy suggests that small and marginal farmers are more efficient than medium and large size farmers. The estimate for the coefficient associated with tractor use is negative, which implies that the farms that use tractor inputs for pond bottom clearing and bund preparation are more efficient. The negative coefficient associated with the percent of water exchanged daily suggests that farms with greater daily water exchange are more efficient than those that exchange their pond water less frequently.[21] The positive coefficient for the *avpnsz* and *nopnds* variables suggest that farms with a greater number of total ponds and farms with a larger average pond size are less efficient.

Weak relationships of interest are the positive coefficient on the years of operation variable and the positive estimate for the coefficient associated with chemical use. The first suggests that shrimp farmers with more years of experience are less efficient while the second suggests that farm managers that employ chemicals to keep the pond water free of bacteria are more efficient. However, both relationships are very weak since the coefficients are insignificant

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[21] This suggests the direct inclusion of a *water* variable as a normal input in future work.

(according to an asymptotic t-ratio).[22] The policy implications of these findings are discussed in the next section.

5.9 Overall Results & Policy Recommendations

The results of both two-stage and single-stage estimation procedures are relatively consistent. Both methods reject the specification of the stochastic Cobb-Douglas production frontier in favour of the stochastic Translog model for shrimp farm data. Each of the significant parameter estimates in both of the two inefficiency models are opposite in sign which suggests consistency between both estimation methods (see earlier discussion).

Overall, the single-stage method is preferred to the two stage approach since it is considered to yield more efficient estimates of the *beta* parameters and therefore more accurate efficiency measures. These results are therefore accepted as a more accurate estimation of the farm specific characteristics and managerial variables that explain farm efficiency in the sample. The single-stage method also identifies several significant variables in the inefficiency model found to be statistically insignificant in the second stage of the two-stage approach. This investigation, therefore confirms what others often suggest, but rarely demonstrate: that the single-stage estimation procedure gives more accurate technical efficiency measures and in doing so, allows a fuller explanation of technical inefficiency amongst shrimp farms.

The overall results of this study of brackishwater shrimp aquaculture indicate that Kandaleru shrimp farms operate below maximum feasible production levels and that there is potential to improve technical efficiency without additional investments in land, labour and capital. Non-traditional brackishwater shrimp farming is relatively new to many of India's regions where it is currently practised. In addition, many farmers adjust their culture methods through trial and error.[23] However, the number of years of experience a manager

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[22] Unless otherwise stated, all tests of hypotheses are conducted at the 5% level of significance.

[23] Personal discussions with Kandaleru shrimp farmers revealed that the method of culture operations was learned primarily by watching family relations culture shrimp. Very few of the sample farmers were trained through the BFDA special training program. Unfortunately, the

or owner-operator has in shrimp culture is found to be statistically insignificant in explaining technical efficiency. This suggests that the most obvious ways known to managers to improve farm efficiency are not sufficient. In personal discussions with Kandaleru shrimp farmers, farm managers themselves conveyed that consistent production of shrimp was somewhat of a lottery, despite the "scientific" methods employed.[24] This analysis, however, seems to contradict this belief.

There are a multitude of factors, both direct and indirect, involved in the shrimp production mechanism. Direct factors include essential inputs needed to culture shrimp. Indirect factors such as managerial practices and farm specific characteristics are known to be important determinants of farm efficiency, but are seldom examined due to a lack of relevant data on managerial inputs (Dawson, 1980). In the next several sections, explanations are offered as to the causes and consequences of technical inefficiency amongst sample shrimp farms.

5.9.1 A Question of Scale/Size

It is clear that technical efficiency is to some degree related to farm size. The positive and statistically significant small farm dummy indicates that shrimp culture on the 40 farms less than 4 hectares of waterspread area are on average 25 percent more efficient than the 42 larger farms.[25] Furthermore, a more detailed breakdown of the technical efficiency figures illustrates that the largest farms in the sample (greater than six water spread hectares) are on average over 35 percent less efficient than the smallest size (less than three water spread hectares) and mid size (between three and six water spread hectares) farms (see Table 5.13).

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survey does not ask farmers to indicate whether they are BFDA educated. Thus, it is not possible to compare the efficiency measures of BFDA trained or funded farmers with the others.

[24] Shrimp farmers engaged in relatively similar culture practices year after year complained of severe output fluctuation. Similarly, several farmers mentioned that output levels fluctuate across ponds on the same farm, despite the fact that the same combination of inputs are used in each and similar management techniques employed. I noticed, however that there are as many dissimilar factors between ponds as similar ones (i.e. irregular pond sizes and location, to mention just two).

[25] Average technical efficiency is approximately 88 percent for smaller farms and 62.6 percent for larger farms.

Table 5.13
Technical Efficiency by Size of Farm[26]

Farm Size	Mean TE	SD	MIN	MAX	# Farms
smallest	.85	.135	.43	.97	25
mid size	.87	.104	.54	.97	30
largest	.49	.298	.01	.96	27
ALL	.75	.262	.01	.97	82

This result is also confirmed by the positive and statistically significant coefficient on *nopds* (the number of ponds per farm) which suggests that farms with a greater number of ponds are less efficient. Together, the negative and significant coefficient on the small farm size dummy and the positive and significant coefficient on the *nopds* variable confirm that size is an important determinant of technical efficiency. The question remains, however, why are larger farms less efficient? Secondly, what proportion of technical inefficiency is a result of scale? The production function approach presented in this chapter is unable to answer these two crucial questions. This is a result of this method's limitations. The issue of scale is further discussed in Chapter 6, which attempts a non-parametric programming approach to efficiency measurement.

5.9.2 Location & Production Environment

Technical efficiency is related to location. In our model, location is equivalent to the production environment, which is used as a proxy for water quality. The statistically significant coefficient on the location dummy suggests that Tikkavaram farms are more efficient than Bestapalem farms. Simple summary statistics (see Table 5.14) suggest that Tikkavaram shrimp farms have a mean technical efficiency index of 0.789 whereas Bestapalem farms have a mean technical efficiency index of 0.715. This result suggests that geographic factors and/or environmental differences between the two shrimp farming clusters are worth exploring further.

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[26] Smaller size farms are defined as those less than 3 water spread hectares; mid-size farms are between 3 and 6 water spread hectares; the largest size farms are greater than 6 water spread hectares.

Table 5.14
Technical Efficiency & Production Environment

Village	Mean TE	SD	MIN	MAX	# Farms
Tikkavaram	0.789	0.235	0.11	0.965	35
Bestapalem	0.715	0.278	0.01	0.970	47

Shrimp farms located adjacent to Tikkavaram village appear to have an advantage in terms of the quality of their surrounding natural environment. First, Tikkavaram shrimp farms operate 42 kilometres upstream from the Bay of Bengal. It is the second shrimp farming cluster located along the Kandaleru creek which means that there is only one adjacent shrimp farming cluster upstream from this group of farms. Bestapalem, by contrast is only 28 kilometres upstream from the Bay of Bengal and has four large shrimp farming clusters and several smaller ones located upstream from it.

Water is one crucial input missing from the original stochastic Translog specification described in (13) and again in the technical efficiency model (15). It is an essential input in shrimp culture. However, it is not the quantity of water that makes a difference to production, but rather the *quality* of water used to fill the pond and used for daily water exchange. Therefore, the quantity of water used per farm as a missing input is not cause for as much concern as is the lack of a water quality index.

It is possible, however that poor intake water quality is a significant reason to why shrimp farms adjacent to Bestapalem village are less efficient than those farms adjacent to Tikkavaram. Thus, the possibility of a classic upstream-downstream externality problem is possible. The hypothesis that technical efficiency is negatively related to poor intake water quality cannot be supported as a result of a lack of appropriate data. Moreover, it is impossible to prove this causality; that is, that poor intake water is the cause of inefficiency.[27]

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[27] The parametric approach enables modelling, measuring and explaining technical inefficiency, but does not enable direct discussion of causation. This research does not attempt to discuss causation.

5.9.3 Mechanisation

The use of machines in the shrimp production cycle is found to positively influence technical efficiency. Specifically, shrimp farms that used tractors for pond preparation and diesel driven pumps for water exchange during the culture period were found to be more efficient than those that did not.

The negative coefficient on *dtract* implies that shrimp farms that use tractor inputs for pond bottom clearing and bund preparation are more efficient than those that do not. The negative coefficient associated with the percent of water exchanged daily suggests that farms with greater daily water exchange are more efficient than those that exchange their pond water less frequently. Water is pumped into ponds using diesel fuelled pumps which are available in a range of sizes. Large farms were found to have three to four big pumps for this purpose, which were usually kept in a pump house built to store this machinery. Small farms by contrast were found to share a small mobile pump among a group of smaller farmers.[28]

5.9.4 Managerial Factors

Weak relationships of interest include the positive coefficient on the years of operation variable which suggests that shrimp farmers with more years of experience are less efficient, and the positive estimate for the coefficient associated with chemical use which suggests that farm managers that employ chemicals to keep the pond water free of bacteria are more efficient. However, both relationships are very weak since the coefficient is statistically insignificant (by an asymptotic t-test). The number of times the shrimp were fed and whether

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[28] The specific nature of water exchange is also important since disease as a result of polluted effluent water is commonly transported via the common water source. Some farms were found to store their own reserve of clean water in a holding pond for the duration of the culture period. These holding tanks were filled at the beginning of the culture season with water from the Kandaleru. Effluent water was almost always pumped into the Kandaleru on a daily basis. Unfortunately, we did not include a question in our questionnaire that asked whether farms had constructed a clean water holding tank. Smaller farms, by contrast were found to exchange water less frequently, but in almost all cases, the intake water was pumped directly from the Kandaleru or from a small feeder canal leading to the Kandaleru. Water exchange serves several purposes such as replenishing evaporated pond water and replacing dirty pond water with clean water.

the feed was foreign or domestically produced were not statistically significant in explaining farm efficiency.[29]

Technical efficiency appears to be related to the size of the pond. The positive coefficient for *avpndz* suggests that farms with a larger average pond size are less efficient. This suggests that ponds that are larger (and shallower) are less efficient than smaller (and deeper) ponds. As the pond size is directly under the manager's control, this result could directly help to improve farm efficiency. The question remains, however, what is the optimum pond size for our sample?

5.9.5 Farm Specific Characteristics

The results suggest that ownership and corporate status have no statistically significant effect in explaining technical efficiency amongst sample farms. The coefficient estimates for the parameters associated with both variables are negative which suggest that owner-operators and those farms registered as corporate entities are more efficient than those that lease land and that are not corporate entities. However, both relationships are statistically insignificant by an asymptotic t-test.

5.9.6 Missing Variables

The explanatory variables included in the model of the inefficiency effects, while indicating the importance of management factors and farm specific characteristics, do not fully capture the extent to which management decisions can explain the variation of technical efficiency in brackishwater shrimp aquaculture. Future studies should be designed to elicit more specific data regarding factors affecting managers' decision making processes. For example, education level may be useful in addition to the variable *yrsop* which marks the

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[29] It is likely that the *dfeed* dummy variable may not separate out those farms using high-tech feed produced abroad and those using low tech feed produced locally, as was originally intended. It is possible that shrimp farmers may have purchased feed manufactured locally by multi-nationals. This means that feed domestically produced may be high-tech feed, although domestic in origin. The variable is included it to identify whether feed produced locally or foreign manufactured feed makes any significant difference in the technical efficiency predictions.

number of years the farm has been culturing shrimp. This variable is used to proxy managerial experience.

Another variable that may be useful in explaining technical efficiency and not included in the models is whether the manager has received any specialised government or private sector training in shrimp culture. Discussions with farmers revealed that managers of several large farms went as far as Thailand and Indonesia for specialised training. In contrast, owner-operators of smaller farms claim to predominantly "learn by doing".

In addition, many larger farms contained small laboratories to test pond water quality. A question asking respondents whether they use scientific methods to test water quality may help to explain efficiency variation among farms. Obviously, there are many more factors that could be included. Overall, more detailed data on managerial and farm specific characteristics allows for better explanations on the variation of technical inefficiency in Indian shrimp culture systems.

5.10 Conclusions & Areas for Further Research

The Indian Supreme Court decision to ban all forms of non-traditional shrimp aquaculture has driven the industry to a stand-still. One well known consequence has been a financial crises for rural producers of shrimp. A second consequence has been the decline in foreign receipts brought into the country from farmed shrimp exports. Current parliamentary debate has focused attention on devising a method with which to effectively regulate the industry and thereby allow it to continue along clearly defined lines. Specifically, this commission has been set up to generate concrete solutions to ensure the sustainable development of this industry. To this effect, the first challenge is to assess the performance of the industry and secondly, to rigorously examine what types of farms are responsible for alleged negative externalities, both environmental and socio-economic.

This chapter deals directly with the first issue and provides a rigorous methodology in which to model, measure and explain technical efficiency in shrimp farms using parametric approaches. The results are based on primary data collected at the farm level which enables greater depth in analysis. In addition, a good account of what farm specific and managerial characteristics have a positive or negative impact on technical efficiency is provided. Scale, production environment, and farm mechanisation are important variables in explaining technical efficiency. In fact, from summary distributional statistics we see that small and medium size farms are on average over thirty percent more efficient than large size farms and that water quality may affect shrimp farm productivity. Moreover, farm mechanisation is associated with more efficient farms.

Appendix 5A

Efficiency Indices

Table 5A.1

Efficiency Index for Sample Shrimp Farms
Stochastic Production Frontier (preferred model)

Farm	*Index*	*Farm*	*Index*
1	0.880523	42	0.638567
2	0.437072	43	0.849831
3	0.889835	44	0.851854
4	0.798151	45	0.828577
5	0.796105	46	0.901584
6	0.958702	47	0.943085
7	0.743510	48	0.936154
8	0.926662	49	0.775921
9	0.959009	50	0.792368
10	0.545658	51	0.910577
11	0.712821	52	0.930350
12	0.969191	53	0.907209
13	0.959380	54	0.933428
14	0.927878	55	0.633064
15	0.733268	56	0.853676
16	0.949038	57	0.933383
17	0.953400	58	0.542707
18	0.948741	59	0.789575
19	0.935711	60	0.920836
20	0.886751	61	0.961897
21	0.798016	62	0.866248
22	0.918008	63	0.935710
23	0.947939	64	0.362917
24	0.801861	65	0.545527
25	0.902015	66	0.442005
26	0.859372	67	0.415681
27	0.957901	68	0.581768
28	0.918761	69	0.510038
29	0.898682	70	0.207916
30	0.948073	71	0.471691
31	0.908605	72	0.333264
32	0.934167	73	0.356645
33	0.944162	74	0.106997
34	0.965244	75	0.647221
35	0.965723	76	0.246451
36	0.928504	77	0.233221
37	0.950557	78	0.580003
38	0.934588	79	0.214759
39	0.939287	80	0.079483
40	0.939476	81	0.113309
41	0.908377	82	0.001128

Chapter 6

Measurement of Kandaleru Shrimp Farm Productive Efficiency

-A (Non-Parametric) Data Envelopment Analysis-

6.0 Introduction

In the stochastic production frontier approach (PFA) discussed in the previous chapter, small and medium size farms were found to be more efficient than large and corporate farms. The econometric results suggest that scale economies may exist in the shrimp farming sector. While the parametric investigation enables some analysis as to why larger farms are generally less efficient, the PFA is unable to determine what proportion of total productive efficiency is a result of scale.

Investigation into the importance of farm size and scale of culture operation in the efficiency debate is possible using non-parametric data envelopment analysis (DEA). DEA requires a linear programming procedure to minimise inputs per unit of output in order to determine the frontier of best-practice farms. The efficiency of each farm is assessed relative to the best practice frontier. Unlike parametric frontier analysis, DEA enables separation of the total efficiency index into scale adjusted technical efficiency or pure technical efficiency and scale efficiency. Thus, it is possible to examine whether any inefficiencies are a result of the farm being an inappropriate size, or whether the farm manager is not combining inputs in the most efficient way. This is possible as a result of relaxing the assumption of strong disposability and constant returns to scale assumption that constrains most parametric models.[1]

There are also additional strengths of DEA that make it useful to practitioners. Unlike the parametric approach which requires some data manipulation, DEA uses the available data in its original form. The input levels, for example, need not be greater than zero as is required in PFA. Moreover, DEA does not include a disturbance term in estimating the frontier nor does it use

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[1] For a detailed discussion regarding the evolution of DEA between 1978 and 1995, see Seiford (1996).

any residual in computing the efficiency index. DEA also does not presuppose any specific production technology such as Cobb-Douglas or Translog, which must be specified in the parametric frontier approach. Overall, there is some debate between practitioners as to whether PFA or DEA provides greater insights in estimating productive efficiency of farms. This research, however suggests that given each method's restrictive assumptions, both methods are employed to fully explore the issue of efficiency.

This chapter discusses both the theoretical construction of DEA and its application to the 82 Kandaleru shrimp farm sample in six sections. Section 6.1 presents a brief review of the literature and discusses international evidence on the origin of scale economies in agriculture. Some conjectures are also made regarding the shrimp farm sector based on local conditions. Section 6.2 presents the linear programming problem and the formal DEA model. A brief overview of the data is presented in section 6.3. The empirical estimation of total, pure technical and scale efficiency is presented in section 6.4. In addition, the importance of farm size is discussed and the origins of scale economies in Indian shrimp farming are examined. In this respect, the role of past and current policies in determining the observed productivity relationships is examined. Section 6.5 concludes with a brief comparison between PFA and DEA methods and results.

6.1 Overview of the literature

6.1.1 International Experience

There appears to be a general consensus in the literature suggesting that economies of scale do not exist in agriculture and most empirical studies conclude that farms exhibit constant returns to scale (Johnson and Ruttan, 1994).[2] When scale economies do exist, however, the source is attributed to factors such as lumpy inputs (i.e. mechanisation and managerial experience), missing or imperfect markets (i.e. a lack of access to credit) and/or the existence of plantation type

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[2] See Binswanger et al. (1993) for a comprehensive review of efficiency studies with respect to agriculture.

farming which combines crop production and processing on a given farm.[3] Managerial skills and increasing farm mechanisation, access to credit, diffusion of risk and on-farm ancillary industries are typically associated with farms with larger land holdings. Several studies have shown that the marginal cost of total farm operation often reaches its minimum over larger farm areas (Binswanger et al., 1993). That is, larger farms are more efficient than smaller farms.

There is general consensus that market imperfections often produce an inverse relationship between farm size and productivity. This occurs especially if more than one market is imperfect. Binswanger (1995:4) concludes that,

> ...if credit is rationed according to farm size, but all other markets are perfect, land and labour market transactions will produce a farm structure that equalises yields across farms of different operational size. But, if there are imperfections in two markets, land rental and insurance, or credit and labour, a systematic relationship can arise between farm size and productivity.

In contrast, there are numerous studies in the developing country literature, and particularly on South Asia, that conclude that smaller farms are more productive and more efficient than larger farms per unit cropping area. Binswanger et al. (1995) suggest that this is true since labour relations in smaller farms are generally better organised and incentive structures are clear. This is particularly true as smaller farms rely on family labour or locally hired hands when additional labour requirements are needed. This notion is supported by several other well known farm studies.[4]

However, Binswanger et al. (1993) argue that when economies of scale arise as a result of unequal access to farm machinery, to managerial expertise and to credit, the minimum efficient farm size increases by less than expected. This, they argue is a result of rental markets. The opportunity of renting farm machinery such as tractors tends to close the efficiency-size gap. Similar to farm machinery rental markets, it is possible that small farmers may also benefit from specialised public advisory services, extension services or private consultation not available to

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[3] Plantation type farms do not exist in this region. Corporate farms tend to have the farming and processing operations in different localities. This is mostly a result of poor infrastructure (i.e. electricity for cold storage, roads for easy transportation, etc.) available along brackish water areas to support ancillary industries.

[4] See Binswanger et al (1993); Binswanger and Kinsey (1993); Binswanger and Elgin (1992) and Berry and Cline (1979).

larger farms (Binswanger et al, 1995). In addition, inter-linked credit markets that offer tied credit to small and marginal farmers discourage them from exiting the sector. With respect to the shrimp farm sector, it is unclear which effects dominate.

6.1.2 Local Experience

Commercial shrimp farming is distinctly similar in many ways to that of commercial agricultural production. Therefore, the size-efficiency debate that takes place with respect to agriculture probably transfers to the shrimp farming sector. However, there are as many differences between traditional agricultural production and shrimp production as similarities. Several are mentioned briefly.

First, in agriculture, small farms are often credit constrained. This is a result of imperfect rural credit markets and the fact that finance institutions are unwilling to lend to farmers without collateral. While rural credit by India's national bank for agriculture and rural development (NARBARD) and government grants exist for small and marginal shrimp farmers, it is unclear as to their impact. Second, in agriculture, mechanisation and managerial experience increase with farm size. Shrimp farming appears to follows a similar path. Larger shrimp farms tend to use mechanical aerators and water pumps and employ university educated technical specialists and temporary consultants. Smaller farms, however, require fewer capital inputs and are less mechanised. While small and marginal farmers do have limited access to government extension programs, it is clear that only a minority benefit from these services (BFDA, 1997). Third, while risk is usually a decreasing function of size in agriculture, the opposite may be true of shrimp aquaculture. The data suggest that larger farms are engaged in more intensive culture practices (see Chapter 3). Moreover, intensive culture practices are alleged to cause aquatic environmental pollution and crop disease when the carrying capacity of the pond is breached (APO, 1995). Fourth, smaller shrimp farms employ family labour and hire local inhabitants while larger farms tend to hire employees from outside the region. This is unlike local agriculture, which tends to hire locally. Overall, it is difficult to discern which effects dominate.

The question remains, what is the overall net effect of competing advantages and disadvantages due to farm size and the intensity of culture? An answer to this question lies in conclusions drawn from answers to several questions posed in the literature with respect to shrimp farming. They include,

- What is the range of productive efficiency of shrimp farms?
- Do scale economies exist in shrimp farming? And if so, do shrimp farms exhibit increasing, constant or decreasing returns?
- What are the origins of scale economies in shrimp farming?
- What relationships exist between efficiency and characteristics associated with environmental sustainability?

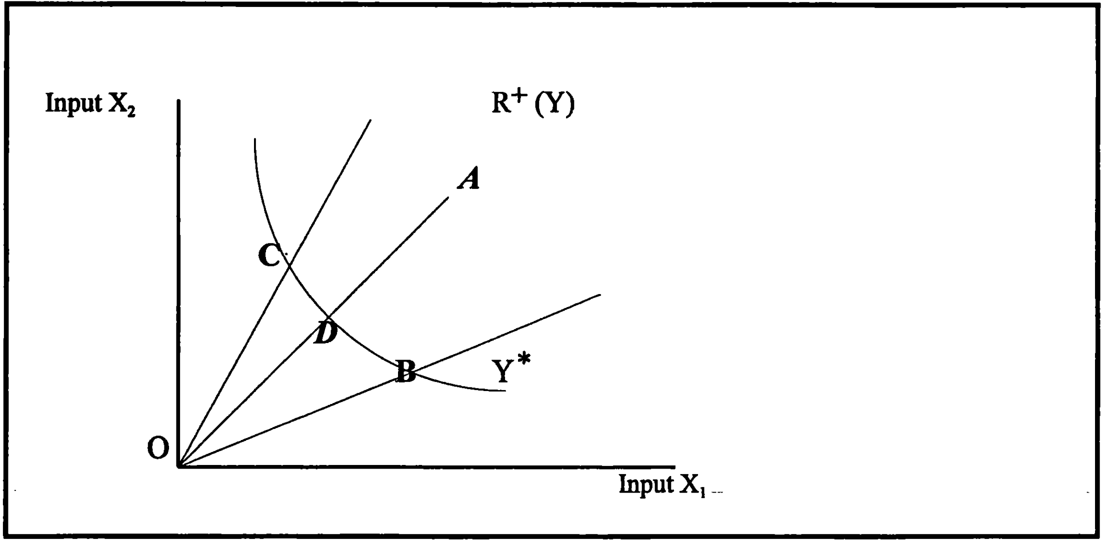
These questions are discussed in the context of the data envelopment analysis model applied to Kandaleru shrimp farm data in Section 6.4 of this chapter.

6.2 Data Envelopment Analysis: Method & Model

6.2.1 The Method

The non-parametric method used to measure the efficiency of Indian shrimp farms is called data envelopment analysis (DEA) and based on the seminal work of Farrell (1957). The Farrell (1957) approach employs a linear programming procedure to determine the frontier of best-practice firms and then to determine the efficiency of each production unit relative to that frontier. The efficiency frontier is defined by minimising the mix of input requirements to produce a unit of output. It is defined such that all firms in the sample are measured relative to the efficiency frontier unit isoquant, Y^* illustrated in Figure 6.0 below.

Figure 6.0
Farrell (1957) Efficiency Measurement



The isoquant Y^* is comprised of the locus of efficient points using the minimum required mix of inputs to produce the unit level of output. It represents the frontier of best practice farms. In the figure above, firms **B**, **C** and **D** are firms found to be efficient and therefore, in part, define the unit isoquant, Y^*. As Y^* represents the efficiency frontier, all firms that fall on Y^* are efficient. The linear programming problem presented in section 6.2.2 formally defines the construction of the isoquant of best-practice firms. In contrast to firms **B**, **C** and **D**, non-frontier firm **A** uses more of both inputs x_1 and x_2 to produce the same unit of output as efficient firm **D** on Y^*. Firm **A** is therefore inefficient. The question remains, by how much?

The segment OD represents the lowest mix of inputs x_1 and x_2 that firm **A** could use and still reach the isoquant, that is produce the same unit output, using its own factor combination. In a sense, it would ideally like to be like firm **D**. The segment OA represents the actual combination of inputs used by firm **A**. Farrell's radial measure of technical efficiency for firm **A** is OD/OA, a value that falls between zero and one. Thus OD/OA measures total efficiency, and includes both technical and scale effects.

6.2.2 *The Model*

Farrell's measure of technical efficiency can be formally expressed as,

$$F_i(y,x) = \text{Min } \Theta \quad \text{where}[\Theta x \in R^+(Y)] \tag{1}$$

where $F_i(y,x)$ is the measure of technical efficiency for farm *i* given the minimum combination of ***x*** inputs used to produce a given level of ***y*** output; Θ is a minimised parameter that represents the amount by which the observed input combination can be reduced. The boundary of the set $R^+(Y)$ represents the best practice unit isoquant. As discussed earlier, the unit isoquant defines the minimum combinations of inputs required to produce some unit output level, Y. The level of efficiency for each farm *i* is defined as the solution to the linear programming problem in (1) and subject to the following constraints,

(1a)	$z_i Y_i \geq y_i$	output constraint
(1b)	$z_i X_i \leq \Theta x_i$	input constraint
(1c)	$z_i \geq 0$	ensures non-negative intensity parameters

where ***x*** is a (n x 1) vector of inputs, ***y*** is a (m x 1) vector of output, ***Y*** is a (m x k) matrix of output, ***X*** is a (n x m) matrix of input combinations and ***z*** is the vector of farm-specific non-negative intensity parameters used to construct combinations of observed inputs and outputs. In this model, *i* indexes each of the 82 farms in the sample. Θ determines the minimum combination of each input needed to produce a given level of output by radial scaling the original observations and their convex sets.

Each constraint plays an important role in estimating technical efficiency. Constraint (1a) is an output constraint. The left hand side constitutes a theoretical efficient farm against which the i^{th} farm output is compared. Constraint (1b) is the input constraint which consists of two parts. The $z_i X_i$ represents the minimum combination of inputs needed to produce an efficient outcome. The right hand side component, Θx_i defines the actual level of inputs needed to produce output y for the i^{th} farm, multiplied by Θ, the amount by which the observed input combination can be reduced. A farm is considered totally efficient when $\Theta = 1$. As a result, the component $z_i X_i$ is exactly offset by Θx_i. Therefore, the level and combination of inputs of the i^{th} farm are the same as the theoretically efficient farm. A farm is considered inefficient when $\Theta < 1$, which indicates that the theoretical minimum level of inputs is less than the actual input level of the i^{th} farm. The final constraint, (1d) ensures that the vector of farm-specific intensity parameters are non-negative.

6.2.3 Decomposing Technical & Scale Effects

The objective of separating scale effects from total efficiency is to assess the degree to which (i) farms operating at an inappropriate size and non-optimal scale of culture operation, and (ii) farms are using less than efficient culture methods. The total efficiency index for each farm can be separated into scale efficiency and scale-adjusted efficiency or pure technical efficiency. Straightforward separation of pure technical and scale efficiency from the total efficiency index is not possible by parametric estimation techniques. The most common approach to determining returns to scale of estimated production functions such as the Cobb-Douglas specification is to sum the coefficients or output elasticities of the estimated model. A sum greater, equal and smaller than one indicates increasing, constant and decreasing returns respectively. While this approach is standard in empirical production economics, Binswanger (1995) warns against this procedure since inappropriate conclusions are easily drawn as a result of simple model misspecifications. As non-parametric models do not require specifying a particular functional form, the method in which returns to scale is measured is less vulnerable to problems arising from model misspecification.

Models in the non-parametric DEA approach are independent of any specific functional form and therefore less restrictive than parametric methods. Furthermore, the data used in DEA is unit neutral which means that it is not necessary for all firms to have positive values for all possible inputs or outputs. The major disadvantages of this approach, however is the lack of straightforward hypothesis tests, the extreme sensitivity of the model to an additional input or output vector and its sensitivity to outliers.

Fare, Grosskopf and Lovell (1985) suggest an extension to Farrell's linear programming problem from which pure technical (PTE) and scale efficiency (SE) is separated out from total efficiency (TE). While TE takes the output level as given, SE is concerned with choosing the maximum output level possible given the available mix of inputs. In measuring the scale effect, constant returns to scale is assumed to be the long-run equilibrium condition. This means that firms are assumed to operate at the minimum of the total cost curve in the long-run. By relaxing this assumption in the short-run, Fare et al. (1985) show that the level of total efficiency for a farm *i*, $F_i(y,x)$ can be decomposed into pure technical efficiency, $PTE_i(y,x)$ and scale efficiency, $SE_i(y,x)$ according to the following relationship,

$$(2) \qquad F_i(y,x) = PTE_i(y,x)SE_i(y,x)$$

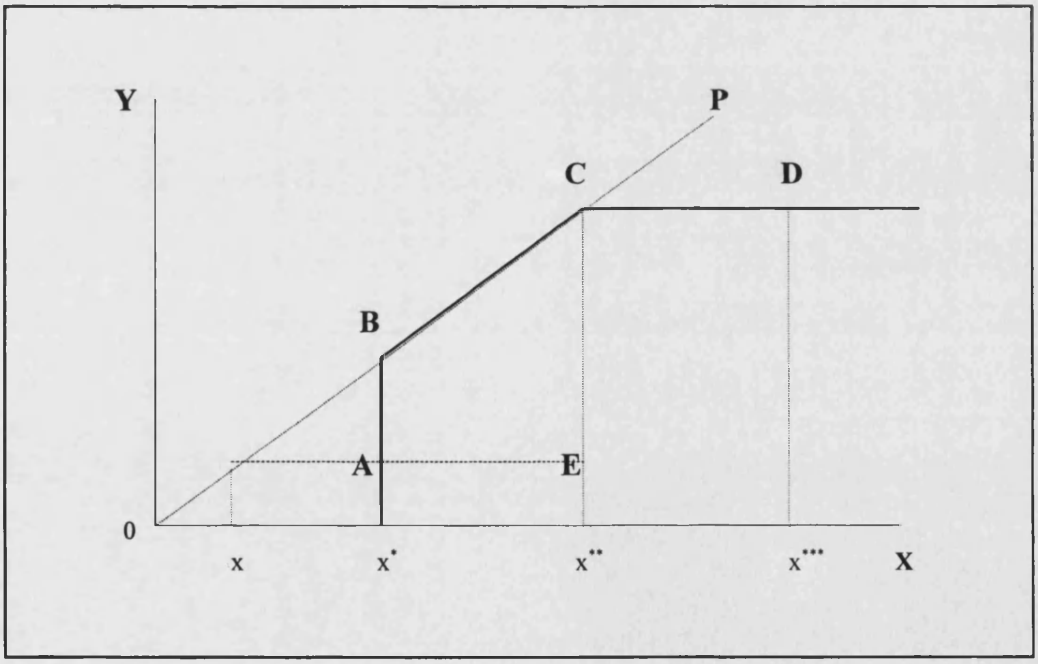
Following this model, $PTE_i(y,x)$ is calculated as a programming problem in which constant returns to scale is not imposed. Pure technical efficiency is therefore measured independently of scale effects. This is achieved by adding an additional restriction to the original programming problem formulated by Farrell (1957). The problem therefore becomes a straightforward extension of (1) and subject to constraints (1a), (1b), (1c) with an additional constraint,

$$(1d) \qquad \sum z_i = 1$$

where the sum of z_i across all *i* inputs is constrained to equal one. This extra constraint on the *z* vector has the effect of enveloping the data more closely. It also allows for variable returns to scale to be exhibited. SE_i takes on a value between 0 and 1 where $SE_i=1$ identifies scale efficiency under local constant returns to scale and $SE_i<1$ indicates that the firm under investigation is not scale efficient (i.e. it does not produce at a scale exhibiting local constant returns).[5] However, the degree to which it is scale inefficient is measured by its distance from one.

Figure 6.1 below uses a production function representation to illustrate this result. This representation is an alternative output maximisation formulation of the problem with firms on the production function defining the frontier and the efficiency of other firms being measured relative to it.[6] With output ***Y*** and input ***X***, the constant returns to scale (CRS) frontier is denoted by the straight line total product curve, OP, which passes through the observations for the efficient firms **B** and **C**. Firms **A** and **D** are inefficient as they lie below the CRS frontier. When the constant returns to scale assumption is relaxed, the technical efficiency frontier, shown by the solid line segments, X^*,B,C,D, is concave. In addition to firms **B** and **C** the input-output combinations of firms **A** and **D** are also technically efficient.

Figure 6.1
Decomposition of Pure Technical & Scale Efficiency



With this representation, scale efficiency, $SE_i(y,x)$, is calculated as $F_i(y,x)/PTE_i(y,x)$, since $F_i(y,x)$ includes both technical and scale efficiency

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[5] Afriat (1972) is one of the first to show that by restricting the intensity vector to sum to one permits increasing, constant and decreasing returns to scale to be exhibited.

[6] See Varian (1984) for a comprehensive discussion of the *dual* and *primal* approaches to efficiency measures.

effects. Extracting the pure technical efficiency effects from total efficiency leaves scale efficiency. Therefore as depicted below, firm **A** is scale inefficient by OX/OX^{*}. Although it exhibits pure technical efficiency, firm **A** is considered too small. Firm **D** also exhibits pure technical efficiency, but is too large. It is scale inefficient by OX^{**}/OX^{***}. Finally, firm **E** is technically inefficient by OX^{*}/OX^{**} and scale inefficient by OX/OX^{*}. It's total level of inefficiency relative to the best-practice frontier is OX/OX^{**}.

6.2.4 Returns to Scale

Returns to scale is a technical property of technology. It refers to the relationship between the combination of inputs and output as all inputs are varied in the same proportion. There are three types of returns to scale that a firm can exhibit: constant, increasing, and decreasing. All have well defined properties (see Varian, 1984). As discussed earlier, the linear programming model presented in (1) with its associated constraints, (1a-1d) can be adjusted to relax the constant returns to scale assumption. Non-constant returns to scale are exhibited when $SE_i>1$. To determine the direction of non-CRS, an additional constraint which imposes non-increasing returns is defined, namely (1e).

Earlier, the constraint on the *z* vector, (1d) $\sum z_i = 1$ was imposed to relax the CRS assumption and allow for variable returns to scale by enveloping the data more closely. This constraint, however, does not determine whether the non-constant returns are increasing or decreasing. It simply informs that non-constant returns to scale are exhibited. To identify whether non-constant returns to scale are increasing or decreasing, the earlier constraint (1d) is replaced by a more powerful scale constraint, (1e). The new and final programming problem becomes,

$$F_i(y,x) = \text{Min } \Theta \qquad \textit{where}[\Theta x \in R^{+}(Y)] \tag{1}$$

subject to

$$z_i Y_i \geq y_i \qquad \text{output constraint} \tag{1a}$$

$$z_i X_i \leq \Theta x_i \qquad \text{input constraint} \tag{1b}$$

$$z_i \geq 0 \qquad \text{ensures non-negative intensity parameters} \tag{1c}$$

$$\sum z_i \leq 1 \qquad \text{defines returns to scale} \tag{1e}$$

All variables and constraints are as previously defined in Section 6.2.2.

In Figure 6.1, with output *Y* and input *X*, the constant returns to scale frontier is denoted by the total product curve, OP which passes from the origin through efficient firms **B** and **C.** The efficiency measure, Θ for firm **A** is the same relative to the constant returns to scale and non-increasing returns schematic in Figure 6.1, but higher relative to the variable returns to scale technology. If the efficiency measure under constant returns and non-increasing returns are not the same, then the returns to scale are decreasing (DRS). The literature states that firms exhibiting constant returns to scale are thought to be efficient; those exhibiting increasing returns are thought to be producing too little; and firms producing at decreasing returns to scale are considered too big.

6.3 The Data

The empirical non-parametric investigation of shrimp farm efficiency in the Kandaleru basin is based on the same 82 shrimp farm primary data set used in the parametric analysis. Total shrimp output per farm is measured in kilograms. The five primary inputs used in producing shrimp are seed, feed, land, labour and aerators. The total amount of seed used by each farm is represented by the total number of PL20 (20 day old post larvae or shrimp seed) purchased. Total farm feed requirements are measured in kilograms. The land variable represents the culture area in water spread hectares. Labour requirements are measured in person-days per farm. The average number of aerators used in each pond multiplied by the total number of ponds on the farm represents the total number of aerators used per farm. The data corresponds to the second and final culture period of the 1996 bumper season. A detailed account of the data collection method is presented in Chapter 2. Summary statistics of the data are presented in Chapter 5.

6.4 Empirical Results

The non-parametric DEA frontier results are summarised in Table 6.0. Approximately nine percent of the farms in the sample lie on the best practice frontier which suggest that the frontier is not determined by a couple of outliers. As discussed earlier, non-parametric frontier measures are constructed using all the data provided on all the farms in the sample. In addition, a specific production technology is not assumed in the calculation of the efficiency indices. The efficiency index for each farm is measured relative to a frontier that shifts depending on which farms are included and excluded from the sample. As a result, the efficiency measure for each farm is susceptible to some degree of fluctuation. However, this analysis includes each of the 82 shrimp farms and excludes none.[7]

This empirical investigation moves beyond the discussion offered in the previous chapter which focused primarily on the relationship between farm and managerial characteristics and total efficiency in Kandaleru shrimp farming. In this section, we focus on the relationship between farm size, culture intensity and pure technical, scale and total efficiency. The idea is to attempt to link the concept of efficiency and sustainability together with respect to the development of shrimp farming. This is of particular interest following the December 1996 Indian Supreme Court ban on shrimp farming.

The results presented in this section are structured around an investigation of answers to four key questions presented in section 6.1.2 and repeated here. First, do scale economies exist in shrimp farming? Second, if scale economies do exist, do shrimp farms exhibit increasing, constant or decreasing returns? Third, what are the origins of scale economies in shrimp farming? Finally, how can knowledge of

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[7] Including all 82 farms enables direct comparison with PFA results. This comparison is presented in the final section of this chapter.

efficiency measures provide insights to effectively regulate the shrimp farming sector along sustainable lines? The first of these four question raised is discussed next.

6.4.1 The Importance of Shrimp Farm Size and Scale of Operation

Data envelopment analysis confirms that the scale of operation is a crucial factor in explaining shrimp farm efficiency. In Table 6.0, pure technical and scale efficiency is extracted from total efficiency. The results suggest an inverse relationship between farm size, scale inefficiency and pure technical efficiency in the Kandaleru shrimp farming sector. While small and medium size farms are on average technically efficient, they remain largely scale inefficient. In contrast, while large and corporate farms are on average scale efficient, they remain largely technically inefficient.

The existence of scale inefficiency among farms in the sample implies that Kandaleru farms are not culturing at the optimal scale of operation to ensure maximum total efficiency. More formally, microeconomic theory suggests that these farms are not operating at the minimum of average cost. They are essentially constrained by their scale of operation, and most likely, their size. This further suggests that if farms were scale-adjusted, overall total efficiency could increase. In fact, when scale-adjusted, the pure technical efficiency for small and medium farms is 99 percent and 87 percent, respectively. In contrast, large and corporate farms, while over 90 percent scale efficient, are on average severely technically inefficient.

Table 6.0

Pure Technical, Scale & Total Efficiency Indices in the Shrimp Farming Industry
(contribution of pure & scale inefficiency to total inefficiency in parenthesis; %)[8]

	Mean Total Efficiency	Mean Pure Technical Efficiency	Mean Scale Efficiency
Smallest Farms less than 2 wsha N=11	65.6	99.9 (0.30)	65.7 (99.7)
Medium Size Farms between 2 and 5 wsha N=34	53.1	87.1 (27.0)	65.1 (73.0)
Large Farms between 5 and 10 wsha N=22	48.1	54.7 (83.3)	90.9 (16.7)
Corporate Farms above 10 wsha N=15	57.9	64.1 (83.5)	92.9 (16.5)
All Farms Average N=82	54.4	76.3 (50.6)	76.9 (49.4)

In all cases, average total efficiency in each size category falls below approximately 66 percent. The average efficiency of the sample is 54.4 percent. The mean total efficiency for the smallest size farms is 65.6 percent. This suggests that these farms are scale inefficient and do not operate at the most efficient size to ensure maximum total efficiency. Adjusted for farm size, the average pure technical efficiency of these farms is at a high level, 99.9 percent. This suggests that scale accounts for approximately 99.7 percent of the inefficiency of the smallest farms in the sample. Medium size farms are similarly constrained by their inefficient size. Scale inefficiency is responsible for approximately 73 percent of these farms' total inefficiency. Technical inefficiency accounts for the remaining 27 percent.

In contrast, large and corporate farms on average suffer from a lack of technical efficiency as opposed to scale inefficiencies. Large farms are on average the most inefficient group in the sample at 48.1 percent. However, less than 6 percent of this size group's inefficiency is a result of scale inefficiency. Corporate farms are on average the most scale efficient group and the second most technically inefficient group in the sample. Technical inefficiency makes

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[8] Calculation is as follows: [(100-PTE)/(100-PTE) - (100-SE)]*100.

up 83.5 percent of this category's average overall inefficiency. Scale inefficiencies account for only 16.5 percent of overall shrimp farm inefficiency. Table 6.1 makes the distinction clear between farm size and the origins of inefficiency in the sample.

Table 6.1
Efficiency and Farm Size, Production Intensity and Feed Use[9]

	Scale Efficient Farms*	Scale Inefficient Farms	All Farms
scale-eff. Index	0.951	0.504	0.763
pure technical-eff. Index	0.604	0.997	0.766
total-eff. Index	0.576	0.502	0.542
number of farms	48 farms	34 farms	82 farms
mean size or culture area	9.22 hectares	2.92 hectares	6.69 hectares
mean stocking density	105,212 seed	57,580 seed	87,688 seed
mean feed conversion ratio#	3.28	1.42	2.59

*defined as those farms with a scale efficiency index greater than the mean, 0.763. These farms exhibit either constant returns (no diseconomies of scale) or weak diseconomies of scale. #kilograms of feed/kilograms of output.

Table 6.1 implies that the farm size-efficiency relationship has its origin in both scale and technical efficiency. This is further underscored by the fact that a large average farm size, high stocking density and a high feed conversion ratio generally characterise scale efficient farms. Meanwhile, the opposite is true of scale-inefficient farms. While it is clear from the above results that smaller farms (with an average farm size of 2.92 hectares) suffer from scale inefficiencies, large farms are technically inefficient (as is also evident from Table 6.0). The above table also suggests that scale inefficient but pure technically efficient farms on average use feed efficiently. This is reflected by the low feed conversion ratio of 1.42 for scale inefficient farms and relatively high feed conversion ratio of 3.28 for scale efficient farms. This result suggests that larger farms are more responsible for excess feeding which allegedly causes environmental pollution.

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[9] The largest and smallest farm is dropped from each farm size category.

6.4.2 *Returns to scale*[10]

While total efficiency is determined by taking the output level as given, scale efficiency chooses the optimal output given a farm's input combination. While it is clear that smaller farms in the sample are relatively scale inefficient (in comparison with larger farms), the following question of importance remains—does the scale of operation need to be adjusted such that a fewer or greater quantity of inputs are used? The answer to this question lies in whether farms are operating under decreasing or increasing returns to scale.

The DEA results reveal that there are scale economies in shrimp farming. ~~Table 6.2 presents the number of farms in each size category operating under~~ constant, decreasing and increasing returns to scale. Generally, a farm is scale inefficient if it is operating at non-constant returns to scale. This means that it is not operating at the minimum of the average cost function. Of the 82 farm sample, 14 farms exhibit local decreasing returns, which indicate that their productivity would be higher if they were smaller (i.e. they are too big); 61 farms exhibit local increasing returns which indicate that they produce too little and could have increased productivity had they been operating at a larger scale (i.e. they are too small). Only 7 farms exhibit local constant returns to scale. These seven farms are perfectly efficient.

Scale economies exhibited by farm size can be further decomposed by those exhibiting strong or weak increasing returns to scale (IRS) and decreasing returns to scale (DRS). The results are illuminating. There is an even distribution of small and medium size farms that exhibit locally increasing returns. In contrast there are no small farms that exhibit locally decreasing returns. This suggests that the smallest sized farms could become more efficient if they became larger.

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[10] In this discussion, firms exhibit *local* returns to scale as opposed to global returns to scale.

Table 6.2

The Number and Percentage of Farms Exhibiting Constant, Decreasing and Increasing Returns to Scale						
	Number and Percentage of Farms exhibiting CRS		Number and Percentage of Farms exhibiting DRS		Number and Percentage of Farms exhibiting IRS	
Smallest Farms less than 2 wsha N=11	1	9.1%	0	0.0%	10	90.9%
Medium Size Farms between 2 and 5 wsha N=34	2	5.7%	4	11.4%	29	82.9%
Large Farms between 5 and 10 wsha N=22	0	0.0%	9	40.9%	13[a]	59.1%
Corporate Farms above 10 wsha N=15	4	26.6%	2	13.3%	9[a]	60.0%
All Farms Average N=82	7	9.0%	14	17.0%	61	74.0%

[a] only 1 large farm and 2 corporate farms exhibit strong IRS (SE < 0.95).

Each of the 11 large and corporate farms exhibiting local DRS have scale efficiency indices of 0.950 or greater. This suggests that while they are considered too big, they are only marginally so. Similarly, a clear majority of large and corporate farms that exhibit IRS have scale efficiency indices greater than 0.90. Only three farms exhibit strong local IRS. The remaining farms are relatively scale efficient. Large and corporate farms are overall, operating at a relatively efficient size.

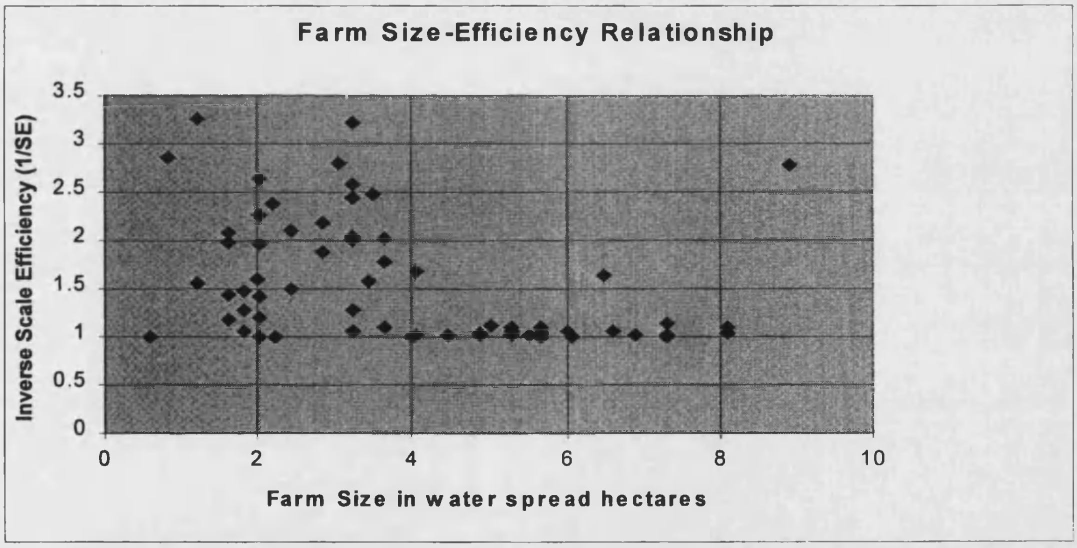
DEA analysis does not provide direct explanations for the advent of scale economies in shrimp farming. The origins of scale economies (or scale diseconomies) and related issues are explored next.

6.4.3 The Origin of Scale Economies

Microeconomic theory suggests that firms exhibiting local constant returns to scale operate at the minimum of the average cost curve. One well established property of the average cost curve is simply that it is a declining function of output under increasing returns to scale, and an increasing function of output under decreasing returns to scale. Chavas and Aliber (1993) suggest that the inverse of the scale efficiency index, approximates the average cost function in its interpretation. This approximation, allows for a graphical investigation into the origin of scale diseconomies in shrimp farms.[11]

In the 82 shrimp farm sample, the farm size-scale efficiency relationship is clear. The inverse of the scale efficiency index for the largest farms in the sample (those greater than ten waterspread hectares) is 1.09 as opposed to smaller farms (those less than ten water spread hectares) which have an average index of over 2.0. Figure 6.3 illustrates that while scale efficient farms exist in every size category, there is clear evidence that economies of scale exist for small and medium size farms. This is a result of the numerous farms operating far above the minimum of the average cost curve or 1/SE >1 (see below). The question remains, why?

Figure 6.2



1/SE can be interpreted as the relative decrease in average cost obtainable from re-scaling output to the point of locally constant returns to scale. Only 18 percent of small farms and 36 percent of medium size farms are relatively scale efficient.[12] These farms used inputs most effectively to produce a given level of output. They are represented in the figure above as those farms falling directly on or around the value 1/SE = 1. For the remaining scale inefficient shrimp

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[11] Chavas and Alibar (1993) make a case for dairy farmers in the United States. The same technique has been applied in other farm level studies (see Binswanger et al., 1995).

farms in the sub-sample, seed, feed, land and labour inputs remain slack. Slack variables are those that do not act as constraints on the linear programming problem derived in equation (1). Although it appears from the figure above that farms of the smallest size have a large variance in scale inefficiency, there exists a strong relationship in the data.

To investigate the exact relationship between scale efficiency and size for the smallest farms, the Pearson correlation coefficient is examined. The statistically significant Pearson correlation coefficient of 0.319 in comparing the relationship between scale efficiency and size (for those farms under 5 water spread hectares) suggests that as farms become larger, they become more scale efficient. A similar comparison between scale efficiency and the stocking density suggest that the relationship is not significantly different from zero at ten percent. This suggests that it is farm size and not seed inputs that most likely drive the scale inefficiency in the smallest farms in the sample. The relationship can be represented by a curve, convex to the origin with a slope near one for the smallest farms, and that becomes slightly less steep as farm size increases.

6.4.4 *Factors Contributing to Scale Economies*

DEA analysis measures the efficiency of firms relative to a best practice isoquant. Ali and Seiford (1993) suggest that derivation of the efficiency index can be viewed as the first stage of a two-stage model. They suggest that one or more variable inputs may be slack for firms found both on and off the frontier. A slack input is flagged when the marginal physical product of that input is reduced to zero. This means that input quantities above a given level do not contribute further to creating additional output. A slack variable does not act as a constraint on production in the programming problem and this indicates excess amounts of a given input in the production process. To be fully efficient, a farm should have no slack variable input. The absence of slack inputs suggest that the minimum quantity of each input is used in the optimal proportion to maximise output. The presence of surplus inputs suggests that one way of improving technical efficiency

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[12] 1/SE is less than 1.05 and 1-SE is less than .05 in these cases which suggest that these farms

is to re-adjust the input combination. In fact, a slack input implies that reducing that input relative to the others will ensure that the farm operates at its optimum or most efficient point of production.

With respect to the Kandaleru shrimp farms, knowledge of input slacks provide (in theory) an indication of which farmers are over-stocking, over-feeding, using excess labour, land and capital inputs and by how much. This is, of course, relative to the most efficient combination of inputs to ensure maximum efficiency. Knowledge of input slacks can also help identify characteristics of farms most likely to waste inputs. Wasted inputs are not only expensive for the shrimp farmer (in that the farm operates above minimum average cost), but are also allegedly responsible for polluting discharge water. This is particularly noteworthy in the case of excessive feed use. Similarly, excessively large farms are allegedly responsible for salinity of agricultural land and well water.[13]

6.4.5 Environmental Implications of Input Slacks

Environmental pollution, as a direct and indirect result of shrimp farming is causing alarm throughout shrimp farming nations. Experts agree that water pollution is a direct result of excessive stocking and over-feeding (APO, 1995). According to a scientific report submitted to the Andhra Pradesh Pollution Control Board in 1996, the water quality of the Kandaleru river has deteriorated as a result of shrimp farming (Rao, 1996). The report, based on laboratory examination of water samples taken from over a fifty kilometer stretch along the Kandlaeru, examined eleven water quality indicators. The results suggest that at several localities along the Kandaleru (which according to the report, appear to be near large shrimp farming clusters), the river is unable to support traditional plant and animal life previously living in its waters (Rao, 1996:9-15). In the following sub-section, input slack data generated by DEA methods are examined

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are more than 95 percent scale efficient.

[13] Recall the discussion presented in the first chapter which cites studies claiming the relationship between feed and polluted discharge water. The relationship between well water salinity and the number of ponds or water spread area is presented in Chapter 7.

to explore whether Kandaleru shrimp farms are indeed over-stocking and over-feeding.

Table 6.3 presents the average quantity of slack inputs per water spread area and the percent of excess per farm in each farm size category. A slack input (in this regard) can be defined as the physical amount of inputs used in excess of the minimum amount needed to achieve the theoretically optimal level of productive efficiency. It essentially can be thought of as a surplus amount of input. Dividing the amount of each slack input by the water spread area per farm enables direct comparison between farm size categories. The "percent excess" is the proportion of slack input to the total amount of that input actually used to produce the maximum output, given the input proportions.

Table 6.3

Input Slacks (total amount per water spread hectare) & Percent in Excess

Farm Size	**Seed**	**Feed**	**Land**	**Labour**	**Aerators**
Small	9,758 25.2 percent	42.7 12.0 percent	.095 2.3 percent	9.2 8.3 percent	.3 1.2 percent
Medium[*]	14,089 24.1 percent	195.7 27.6 percent	.129 12.9 percent	40.5 27.4 percent	0.4 10.3 percent
Large	6,551 6.5 percent	22.9 1.5 percent	.214 16.4 percent	15.4 8.8 percent	1.7 45.4 percent
Corporate	5,823 2.2 percent	99.9 1.6 percent	.321 31.2 percent	12.5 4.4 percent	1.1 10.4 percent
ALL	9,968 19.3 percent	111.3 27.5 percent	.213 21.3 percent	24.5 18.7 percent	0.9 18.2 percent

note: [*]dropping farm number 10 reduces the average feed input slack to approximately 100 kilograms. The percent excess falls to approximately 12 percent. The other slacks remain relatively unchanged.

It is possible to use both the efficiency index and the level of input slacks (especially excess feed per water spread hectare) in assessing the sustainability of each shrimp farming system. Improvements in technical know-how and managerial capabilities could have significant direct and indirect costs and benefits. Naturally, these improvements would change the way in which combinations of inputs are used.

In the shrimp farming sector, much of the technology used to rapidly grow shrimp to its maximum size in the minimum amount of time is embedded in feed. Pellet feed contains growth hormones and antibiotics in addition to fish meal, its principle ingredient. Surplus feed (i.e. feed not consumed), settles to the pond bottom and degrades the aquatic pond environment. The combination of over stocking and over feeding can lead to crop disease. This is in turn discharged into common water ways via farm discharge water, or effluent. In this way, one infected farm can infect downstream farms by polluting common access coastal waters.[14]

Of all the principal inputs used in shrimp culture, feed requirements are exceeded on average by 27.5 percent or 111 kilograms per water spread hectare per culture cycle as compared to its minimum use to achieve the optimal efficiency level. Similarly, seed requirements are exceeded on average by 19.3 percent or 9,968 seed per water spread hectare per culture cycle.

It is clear from Table 6.3 that the culture method employed by corporate and large farms waste far less seed than small and medium size farms. Small and Medium size farms tend to over-stock by approximately 25 percent than if they were operating at maximum efficiency. In contrast, the percent excess for large and corporate farms is 6.5 percent and 2.2 percent, respectively--significantly less than smaller size farms. This is clearly a result of the large volume of inputs used during the production cycle. While larger farms tend to use seed inputs more efficiently than smaller farms, the same cannot be said of feed use.

Corporate farms, on average, over-feed by 100 kilograms per water spread hectare. Although this amount appears small in proportion to the total feed inputs used per water spread hectare (i.e. 1.6 percent), the ramifications are significant. For example, a corporate farm culturing over 25 water spread hectares, over the course of a production cycle wastes 2.5 tonnes of feed.[15] This excess is ultimately responsible for polluting the natural environment. It is discharged as effluent at a specific discharge point into the common access waterway. The consequences can include siltation, eutrophication, oxygen depletion, toxicity which degrade flora, fauna and other bio-diversity of coastal waters (Gujja, 1997:12; Dierberg and Kiattisimkul, 1996).

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[14] See Chapter 1, section 1.3 for a detailed discussion

[15] These comparisons are relative to the most efficient use of feed inputs.

Large size farms, in contrast, appear to over-feed by less than any other size category. Therefore, it is not possible to conclude that it is the largest size farms that are likely to be responsible for over-feeding and thereby polluting the environment. One possible explanation for this result is that large farms are individually owned and usually managed by the owner. Corporate farms, in contrast, are run by hired managers. It may be the case that owner-operators are more likely to manage expensive inputs such as feed more efficiently. The next section explores this idea more fully by examining whether the differences in managerial and/or farm characteristics are useful in explaining differentials in scale efficiency.

6.4.6 The Importance of Managerial and Farm Characteristics

In addition to slack inputs, there are other factors that may contribute to explaining the scale inefficiency of farms. Some variables worth considering in a second-stage model include farm size, the number of years of managerial experience, location, tractor use, chemical use, the origin of feed (foreign made or domestically produced), farm ownership status and corporate status. A second stage regression, similar to that conducted in the second stage of the parametric analysis discussed in the preceding chapter is presented in Table 6.4.

Table 6.4
A Second Stage Regression: Explaining Economies of Scale

Variables	pooled sample		small farms		large farms	
% scale efficient	*coefficient*	*t-value**	*coefficient*	*t-value*	*coefficient*	*t-value*
extensive culture dummy	-4.7039	-0.342	-7.3418	-0.692	-6.6218	-0.423
small farm dummy	-28.9634	-4.144	-36.6605	-3.823	drop	drop
years of managerial experience	1.1328	1.434	2.9992	0.897	1.0473	0.789
location dummy	-0.2117	-0.563	-5.1848	-0.698	6.9356	1.161
tractor use dummy	2.3768	1.757	9.5326	1.177	drop	drop
water pump dummy	-0.6581	-0.098	-6.7982	-0.655	16.910	1.576
daily water exchange (%)	1.2473	1.795	0.1842	0.159	1.7894	2.188
chemical use dummy	-7.0818	-0.427	-14.9913	-0.767	-7.7128	-1.063
foreign feed dummy	-0.0901	-1.201	5.6287	0.877	-0.9361	-0.360
ownership dummy	-6.7036	-1.085	-17.8929	-2.466	17.1294	1.205
corporate dummy	-15.3987	-1.995	-19.0345	-1.045	-18.5769	-2.298
constant	86.9145	16.481	88.1613	3.496	66.8075	3.579
N		82		45		37
R^2		0.49		0.41		0.33
Adj-R^2		0.41		0.25		0.10
Prob > F		0.00		0.00		0.00

note: *t-value greater than 1.63 implies that the explanatory variable is significant at ten percent or better.

The OLS regression results of the pooled sample suggest that the smallest farms in the sample are on average 28.9 percent less scale efficient than larger farms. This confirms the earlier result that the economies of scale are found in predominantly farms operating under five water spread hectares. The positive and significant coefficient on the tractor dummy suggests that those farms that employ tractor inputs are 2.3 percent more scale efficient than those that do not. Daily water exchange practices associated with more intensive culture practices also increases scale efficiency. Corporate shrimp farms are on average 15.6 percent less scale efficient than non-corporate farms. The following discussion on specific characteristics of the Kandaleru shrimp farming productive environment helps to explain some of these results.

(i) mechanisation

The use of machines at all stages of the shrimp production cycle was found to positively influence overall scale efficiency of farms, regardless of size. Specifically, those farms that used tractor inputs for pond preparation and diesel driven pumps and aerators for water exchange were found to be more scale efficient than those that did not. In the case of the smallest size farms, rental agreements between large and small farmers and or sharing arrangements between small farmers make mechanisation possible. The econometric estimation of the large farm sample reveals that tractor use and water pumps reduce scale inefficiency. Both variables are found to be significantly different from zero at one percent significance for the pooled sample.

(ii) managerial expertise and experience

Managers of larger farms and especially corporate farms have more formal educational training in shrimp culture. Corporate entities hire degree holding micro-biologists, fisheries scientists and MBA's to oversee the day to day culture operation of the shrimp farm. In addition, larger farms sent owners and managers to Thailand and Indonesia for formal training programs.[16] Smaller farm owner-operators were less exposed to formal training programs and formal education. In fact, group interviews with small and marginal Kandaleru shrimp farmers revealed that several of them dropped out of school in order to culture shrimp. Nonetheless, BFDA training and extension programs do exist for small farmers. However, only a small proportion of small farmers participated in government sponsored initiatives, mostly due to a lack of funding. The positive coefficient on the years of managerial experience variable suggest that the number of years of shrimp farming experience played a positive role on scale efficiency. However, this variable is not significantly different from zero at the ten percent level.

(iii) labour

In smaller shrimp farms, family and hired labour work closely together which facilitates effective monitoring. In addition, wages are not paid to family members which keep labour costs low. Larger farms tend to hire seasonal workers who may change from season to season, and year to year. They most likely face

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[16] This was found to be a common practice among Kandaleru shrimp farmers.

high transaction costs in the labour market and high supervision costs not faced by smaller farms. According to Table 6.3, the largest and smallest farms in the sample use labour most efficiently given their size. Medium size farms, on average employ 40.5 person-days of labour in excess of the minimum required amount to achieve optimal efficiency. Medium size farms are by far the most inefficient size group at employing the optimal amount of labour.

(iv) access to land

Throughout the Kandaleru region, prior to shrimp farming's boom, land adjacent to brackishwater bodies was owned by either the government or by members of the local population. In the 1996 season, most larger farms were owned and operated by private entrepreneurs or companies who came to the region from outside. In contrast, owner-operators of smaller farms were native to the region, and often from nearby villages.

Over the past ten years, local land has been purchased by outsiders for the sake of shrimp farming (see Chapter 3). There has also been a fair degree of land owned by the government that has been leased, purchased or encroached upon by shrimp entrepreneurs. Generally, there is an imperfect market that does not favour large farmers, who may wish to expand, but are constrained, despite the financial resources. This is most likely a result of a recent unwillingness of local land owners to sell land (and thereby lose ownership rights). Instead, there has been an increasing prevalence in fixed-term leasing arrangements. On the other hand, small and marginal farmers may wish to expand, but may be credit constrained and therefore unable to do so.

(v) access to credit to purchase inputs

It is unclear as to the degree to which small and marginal shrimp farmers are credit constrained. While they may suffer from a lack of available cash to purchase inputs, four arrangements appear to have surfaced to diminish this possibility. First, many small and medium size farmers are involved in an inter-linked or tied credit market with feed manufacturers and processing units. The idea is that the feed manufacturers give pellet feed to the credit constrained farmer in return for exclusive right to that farmer's harvest. Processing plants also offer credit in exchange for the season's produce. In both cases, an agent is involved in picking up the harvest and transporting it to a processing facility. This cost is not assumed by the farmer. Second, government grants are made available to shrimp farmers of all sizes through the Brackishwater Fish Farmers' Development Association (BFDA). However, data on the distribution of funds suggest that only a small number of farms have benefited from this scheme in Andhra Pradesh (BFDA, 1996).

Third, since 1989-1990 India's National Bank for Agriculture and Rural Development (NABARD) has offered credit to shrimp farmers of all sizes. The share of NABARD's fisheries disbursement targeted for brackishwater shrimp culture rose from 9.03 percent in 1989-1990 to 55.86 percent in 1994-1995. The latter year disbursement amounts to over Rs. 562.5 million for the sector (Pathak, 1997). While small farmers do receive NABARD credit, it is unclear as to the proportion that do so. Moreover, the original farm survey did not include a question asking whether each farm benefited from credit.[17] Nonetheless, a NABARD bank is located in Gudur, which is immediately adjacent to the Kandaleru river shrimp farms. It is thus likely that sample farmers did receive this benefit.

Finally, the role of informal credit amongst small farmers in this sector is unclear, but it most likely operates in a similar manor to that of agriculture. The negative and significant coefficient on the small farm dummy suggests that small farms are likely to dramatically increase productive efficiency by culturing over a larger area.

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[17] Details of NABARD's financial outlays are presented in Pathak (1997) who suggests that loan recovery for small and medium scale farmers is between 40-75 percent. In areas where there is a joint effort between NARBARD, the BFDA, and door to door recovery campaigns, the recovery rate jumps to as high as 97 percent (as was witnessed in Orissa).

(vi) risk

Risk of crop loss is a direct function of stocking density and the quality of intake water. Unlike in agriculture, larger shrimp farms face greater risk as they culture shrimp more intensively. This is believed to increase the probability of crop disease. This is simply a result of the unfamiliarity with shrimp culture technology. If more intensive farms get the input combinations incorrect, the result is shrimp fry stress, pond water pollution and eventually disease and crop loss. We hypothesise that the risk-reward ratio is relatively constant and irrespective of farm size, but offer no further discussion.

The estimation results suggest that farms that practice extensive culture are slightly less scale efficient.[18] This is most likely driven by the fact that smaller size farms are more likely to practice extensive culture than larger farms. As already discussed, smaller farms are disproportionately scale inefficient amongst the 82 farm sample.

(vii) Summary

Small farms can increase their productive efficiency by culturing over larger areas. DEA results confirm that they are scale inefficient and exhibit increasing returns to scale (i.e. they are too small). Larger farms, in contrast, could increase productive efficiency by scaling down the intensity of culture operations, although scale-adjusted pure technical efficiency is a moderately acceptable 83 percent.

6.4.7 Feed Conversion Ratio and Technical Inefficiency

DEA separates technical efficiency into pure and scale inefficiency. While origins of scale efficiency were discussed in the preceding sub-section, this sub-section examines the origins of pure technical efficiency found to exist amongst the largest farms in the Kandaleru shrimp farm sample. In this context,

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[18] However, the coefficient is not significantly different from zero at ten percent.

the relationship between pure technical efficiency and the feed conversion ratio is explored. This is of particular interest as shrimp farm owners and managers use the feed conversion ratio (FCR) as a measure of their overall productive performance.

Pure technical inefficiency occurs when, with the existing technology and input combination, a farm could produce more output with the inputs it employs (or the same level of output with fewer inputs). The presence of pure technical inefficiency as the major source of total inefficiency in large and corporate shrimp farms may suggest the inability of these farms to solve technical problems in the production process. The consequence of pure technical inefficiency is ultimately a reduction in output levels from what is theoretically possible.

The shrimp farming sector has adopted the Feed Conversion Ratio (FCR) as a measure of feed use efficiency. The FCR is constructed as the ratio between the weight in kilograms of feed used and the weight in kilograms of shrimp produced. Sector specialists suggest that the feed conversion ratio of shrimp feeds produced in India range from 2 to 5, while that of imported feeds have a range of 1.2 to 1.8 (Sukumaran et al., 1990). The FCR for sample Kandaleru shrimp farms investigated in this dissertation range from a very efficient 0.98 to over 9.4. A discernible pattern, however, does appear to exist: larger farms tend to use feed less efficiently than smaller farms. This conclusion was also supported by input slack data generated by DEA and presented in Table 6.3. The question remains, what is the exact relationship between the pure technical inefficiency measure constructed by DEA and the feed conversion ratio?

Large and corporate shrimp farms are technology intensive. With stocking densities in excess of 200,000 seed per water spread hectare and average feed conversion ratios at highly inefficient levels (4.83) it is likely that large and corporate farms are technically inefficient as a result of the excessive use of feed inputs.[19] In fact, the efficiency index and feed conversion ratio (FCR) of sample

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[19] High stocking densities and intensive feed use are significantly and positively correlated with each other (see Table 3.4 in Chapter 3). Moreover, as discussed earlier, evidence exists to suggest that intensive seed and feed use is most likely responsible for crop disease and fish-kills. Smaller Kandaleru sample farms, in contrast, enjoy an average feed conversion ratio below 1.5.

shrimp farms are negatively correlated and significant regardless of the modelling approach or statistical method employed (see Table 6.5). This suggests that the most technically efficient farms use feed efficiently. That is to say, the FCR of the most efficient farms, is on average 1.4 or less.[20]

Table 6.5
Pearson, Spearman & Kendall Measures of Correlation
Efficiency Indices *v* Feed Conversion Ratio

Correlation Techniques	Parametric approach	DEA approach
Pearson Correlation Coefficient		
total efficiency	-0.63^{**}	-0.08
pure technical efficiency		-0.29^{*}
scale efficiency		0.25^{*}
Spearman Rank Correlation		
total efficiency	-0.55^{**}	-0.01
pure technical efficiency		-0.13
scale efficiency		0.25^{*}
Kendall Rank Correlation		
total efficiency	-0.39^{**}	-0.01
pure technical efficiency		-0.10^{**}
scale efficiency		0.17^{**}

* indicates significant at 10 percent level; ** indicates significant at 5 percent level

6.5 Comparing Non-Parametric and Parametric Results

Non-parametric data envelopment analysis (DEA) has become increasingly popular in the analysis of productive efficiency. However, less effort has been directed toward comparisons between DEA and other competing efficiency models (see Hjalmarsson et al, 1996 for one recent comparison). This section briefly reviews the methods and the results offered by both parametric and non-parametric models as applied to 82 Kandaleru shrimp farms. Comparing and contrasting the results of each method is useful in that it reveals the advantages and limitations of both estimation methods and suggests when to interpret results with some degree of caution.

The choice of parametric or non-parametric models to measure farm efficiency depends on economic behavioural assumptions of both methods and data

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[20] See Table 6.1.

constraints. The efficiency indices generated by parametric production frontier approach (PFA) are obtained by estimating the best practice frontier using maximum likelihood techniques. The parametric approach has several advantages, including its capacity to provide significance tests for inputs and an overall goodness of fit for the model. One disadvantage of this approach is that the model may be incorrectly specified and therefore yield inappropriate efficiency indices. Moreover, it is unable to separate scale effects from the total efficiency measure. Other limitations and strengths of this approach are discussed earlier in this chapter.

The non-parametric frontier is deterministic in nature and constructed from a linear programming model. The model is capable of handling zeros in the input mix and does not include a disturbance term to capture noise. The efficient frontier is constructed from the solutions of each linear programming problem which minimises inputs in the production process for a given output level. The efficiency level of each farm is calculated relative to this frontier as the ratio of actual to potential performance. One clear advantage of the non-parametric model is its ability to separate scale effects from total efficiency. One disadvantage is that DEA results are swayed by outliers. Another, is that there are no significance tests for inputs or an overall measure for goodness of fit. Nonetheless, DEA's overall appeal is simply that it allows the comparison of each firm with a given input-output combination with others in the sector.

Table 6.6 presents a breakdown of technical efficiency levels for each size group. The data used to construct this table comes from the estimation of all 82 farms using both parametric and non-parametric techniques. The results are therefore comparable across rows and columns.

The parametric efficiency measure in (A) are derived from the general specification of the Translog model estimated in Chapter 5. The non-parametric efficiency measures in (A) represent total efficiency for each of the 82 farm sample. The parametric efficiency measures in (B) are derived from the preferred single-stage stochastic Translog model estimated in the previous chapter. The DEA efficiency measures used in (B) are the scale-adjusted pure technical efficiency measures. The results of both parametric and non-parametric results suggest that there appears to be an efficiency-size relationship.

Table 6.6
Summary Efficiency Measurement
Parametric & Non-Parametric Frontiers

(A)		PARAMETRIC STOCHASTIC TRANSLOG GENERAL MODEL				NON-PARAMETRIC DEA MODEL TOTAL EFFICIENCY			
	N	MEAN	SD	MIN	MAX	MEAN	SD	MIN	MAX
Small	12	**0.801**	**0.169**	**0.437**	**0.969**	**0.656**	**0.228**	**0.306**	**1.00**
Medium	34	**0.902**	**0.071**	**0.638**	**0.969**	**0.531**	**0.163**	**0.311**	**1.00**
Large	22	**0.774**	**0.196**	**0.362**	**0.961**	**0.480**	**0.140**	**0.267**	**0.832**
Corporate	14	**0.323**	**0.222**	**0.001**	**0.747**	**0.579**	**0.286**	**0.179**	**1.00**
All	82	**0.747**	**0.260**	**0.001**	**0.969**	**0.544**	**0.199**	**0.179**	**1.00**

(B)		PARAMETRIC STOCHASTIC TRANSLOG PREFERRED MODEL				NON-PARAMETRIC DEA MODEL PURE TECHNICAL EFFICIENCY			
	N	MEAN	SD	MIN	MAX	MEAN	SD	MIN	MAX
Small	12	**0.776**	**0.181**	**0.495**	**0.971**	**0.998**	**0.266**	**0.995**	**1.00**
Medium	34	**0.898**	**0.064**	**0.648**	**0.966**	**0.871**	**0.001**	**0.386**	**1.00**
Large	22	**0.756**	**0.208**	**0.313**	**0.955**	**0.566**	**0.222**	**0.307**	**1.00**
Corporate	14	**0.161**	**0.116**	**0.103**	**0.325**	**0.641**	**0.211**	**0.195**	**1.00**
All	82	**0.709**	**0.302**	**0.103**	**0.971**	**0.763**	**0.280**	**0.195**	**1.00**

note: N is the number of sample farms in each category

For a given set of data, the estimated technical efficiency indices obtained by fitting a stochastic frontier are usually higher than those obtained by fitting a deterministic frontier (Hjalmarsson et al., 1996). This is a result of the technical construction of DEA which is constructed such that no output values exceed it. In addition, noise is embedded in the inefficiency measure. DEA results are usually lower since only five inputs are used to construct the frontier of best practice farms. This often limits the effectiveness of the linear programming problem. Alternatively, PFA enables estimation of the efficiency index using the same five inputs in addition to nine other variables, including dummies.

The efficiency indices in (A) above confirm the general characteristic that PFA yield higher efficiency measures than DEA. Mean efficiency is 0.747 using parametric techniques as compared to 0.544 using the DEA approach. There are, however some sharp contrasts between the two approaches that may be some cause for alarm. First, while medium size farms are the most efficient size group using parametric analysis, they are the least efficient according to DEA results in

(A). Second, parametric analysis suggests that corporate farms are over 68 percent inefficient on average. DEA results reveal a mean inefficiency of no more than 42 percent for the same size group. The opposite holds true for the comparative measures in (B).

The non-parametric efficiency measures in (B) are on average slightly higher than that of the parametric estimates. While the parametric efficiency measures are similar for both the general and preferred stochastic translog model, they are quite different for the two non-parametric efficiency measures. Unlike the total efficiency measures presented in (A), the pure technical efficiency measures in (B) reveal that the smaller size farms are clearly more efficient than the larger size farms in the sample. Whereas corporate farms are by far the least efficient group according to the parametric results in (B), they are a close second to large farms according to the non-parametric approach. Small farms are 77.6 percent efficient according to PFA while approximately 99.8 percent efficient in the DEA results. With differences such those mentioned above, the question remains, is one approach more appropriate than the other?

The literature suggests some general guiding principles. If a sector is subject to random shocks, the stochastic production frontier approach is considered more appropriate than DEA (Hajalmarsson et al, 1996). The shrimp farming sector does face shocks in the form of crop disease. Since the data are from the bumper harvest year of 1996, it is likely true that the most inefficient farms are those that faced some degree of crop loss as a result of disease. The literature also suggests, however, that efficiency measures by themselves are not the most appropriate for comparison. Rank order of farms (according to the efficiency index) may be more appropriate.

Table 6.7 presents direct comparisons between the two methods employed to calculate efficiency measures. The table below presents the extent of variations in the efficiency indices using Pearson, Spearman rank and Kendall rank correlation methods. The results suggest that overall, there is a weak degree of consistency between parametric and non-parametric approaches.

Table 6.7
Pearson, Spearman & Kendall Measures of Correlation
A Comparison of Parametric & Non-Parametric Efficiency Indices

Correlation Techniques	PFA Parametric stochastic single-stage	DEA Non-parametric total efficiency
Pearson Correlation Coefficient		
total efficiency, DEA	0.0013^{**}	1.0000^{**}
pure technical efficiency$^{(a)}$	0.2868	0.3621^{**}
scale efficiency	-0.3087	0.4499
Spearman Rank Correlation		
total efficiency, DEA	0.1304	1.0000^{**}
pure technical efficiency$^{(a)}$	0.2673^{**}	0.4156^{**}
scale efficiency	-0.3157^{**}	0.4161^{**}
Kendall Rank Correlation		
total efficiency, DEA	0.0949	1.0000^{**}
pure technical efficiency$^{(a)}$	0.1692^{**}	0.3883^{**}
scale efficiency	-0.2174^{**}	0.3555^{**}

* indicates significant at 95 percent level; ** indicates significant at 99 percent level
(a) the pure technical efficiency measure is scale adjusted

The Pearson correlation coefficient suggests that there is no association between the efficiency indices. However, this coefficient is well known to be seriously affected by outliers (Newbold, 1991). Moreover, tests on it require an assumption of normality. Spearman rank correlation, in contrast, is neither susceptible to extreme values nor does it require the normality assumption. It can be used to test the null hypothesis of no association between a pair of random variables. In the table above, the result confirms that there is no association between the DEA and PFA total efficiency measure. In contrast, decomposing total efficiency into scale and pure technical and conducting the same test suggests a degree of association. The positive and significant rank correlation between PFA and DEA's pure technical efficiency index and the negative and significant correlation coefficient for scale efficiency suggest that the hypothesis of no association is rejected.

6.6 Conclusion

While the individual efficiency results from both the parametric PFA and non-parametric DEA differ as a result of each model's behavioural assumptions and construction, the overall trend is very clear. While generally scale-inefficient, the culture methods employed by small and medium size farms make them more technically efficient than large and corporate farms. This suggests that by enabling small and medium size farmers the opportunity to increase their land holdings, average efficiency would rise to near perfect levels. The inefficiency of large and corporate size farms, in contrast, is a result of mostly technical inefficiency and not scale inefficiency. The largest farms are on average over 90 percent scale efficient. They are, however, culturing shrimp more intensively than necessary. In fact, by boosting production intensity to semi-intensive and intensive levels, these farms are on average, operating below their potential maximum efficiency.

There are several environmental and economic implications of inadvertently boosting culture intensity to inefficient levels. First, over-feeding is known to pollute the pond environment. In conjunction with keeping stocking densities high, over-feeding serves as a catalyst for the appearance of several types of deadly shrimp viruses. Shrimp disease is transported to other farms through discharge water. The same discharge water is responsible for polluting near shore areas of coastal estuaries and other brackish water bodies supporting shrimp farming. Second, input use in excess of the minimum combination necessary to ensure a given level of output suggests that firms operate above minimum average cost. This implies that farms are unnecessarily spending money on unneeded inputs.

It is clear from the results that farms that are likely to be credit constrained (i.e. smaller farms) are forced to culture less intensively. Ironically, modified intensive culture is more likely to yield more technically efficient outcomes than more intensive culture operations. For this reason, the handicap usually associated with imperfect markets may not apply in the case of Indian shrimp farming. Unfortunately, the same pure technically inefficient farms are too small, and would benefit from becoming larger. The problem lies in the fact that larger farms culture more intensively, and on average exhibit a moderate degree of pure technical inefficiency. A trade-off is therefore found to exist between scale efficiency and pure technical efficiency in Indian brackish water shrimp aquaculture. Knowledge of this fact provides an opportunity to manage the growth of the sector along sustainable lines.

A strong regulatory framework capping shrimp farm intensity could provide a pareto improving solution to all parties concerned. Reducing culture intensity implies generally scaling down factor inputs, thereby saving natural resources. If large and corporate farms scale down factor inputs, they are likely to reap cost saving and profit raising benefits. The incidence of disease and polluted effluent discharge could be reduced from less intensive culture practices. Thus, the amount of stress currently placed on the carrying capacity of the ecosystem would lessen, easing concerns from environmentalists.

There are some drawbacks. This type of regulation constrains large farms that consistently operate efficiently. However, consistency, in this respect, has not been achieved in this sector. In fact, 1996 will be known as the year of India's first nation-wide bumper harvest, although it remains to be seen if it can be repeated. Therefore, until better technology and managerial practices become known, it is perhaps in the best interest of the Indian nation to limit the intensity of culture operations in brackish water shrimp aquaculture.

Part III

Assessing Social and Environmental Impacts of Shrimp Farming

An Introduction

In response to a social movement against brackishwater shrimp aquaculture (shrimp farming) initiated by S. Jaganathan, an Indian social activist, the sector was recently banned in India (*S. Jaganathan vs G.O.I, December 13, 1997*). Indeed, the alleged intensity of social impacts on rural communities appears to have played a heavy hand in tipping the scale in favour of banning the shrimp farming sector. The Indian Supreme Court (SC) decision in December 1996 provided fuel for activists in other countries to help shut down this sector. In fact, in 1997 an international embargo on shrimp produce was initiated by a conglomeration of western NGOs (Bundell & Maybin, 1996). While activists have correctly pointed out some of the social and environmental consequences of shrimp farming, much of the hard evidence presented to the SC on the severity of social impacts on rural populations as a result of this sector is anecdotal at best. Moreover, the many positive benefits enjoyed by poor coastal regions have not been taken into account. It is unclear, therefore, whether the ban on the shrimp farming sector is actually helping to protect, or further hindering the development of coastal regions.

The Indian Supreme Court's stand is unambiguous: shrimp farming is responsible for degrading the environment and displacing rural people (SC Notification, 1997: 3). The combination of these two factors has led to its ban. However, as claimed throughout this thesis, substantive evidence to support its decision is lacking. Moreover, the field evidence presented to the court in the form of the NEERI Report has been discredited by international experts.[1] Other commissioned "expert" committee reports such as the Suresh Committee Report are equally anecdotal and based on observation as opposed to scientific findings.

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[1] See Chapter One, Section 1.4.5 for a critical review of the NEERI Report and its findings.

Therefore, it is perhaps fair to say that the ban is based on reasonable "perceptions" as opposed to scientific evidence or "facts".

Perceptions, however are important to gauge. In fact, in the economics literature, Clark and Oswald (1996) suggest that there is growing evidence that subjective data serve as strong predictors of observed behaviour. While not explicitly mentioned, this argument, in spirit, was the common thread that ran through the SC proceedings. Based on the assumption that perceptions can adequately represent reality, inhabitants of twenty-six villages were asked to share their perceptions on the negative impacts they face as a result of the advent of the shrimp farming sector in their region. Based on survey results, it is possible to conclude whether the Supreme Court's perceptions of the problems faced by coastal inhabitants match the perceptions on the ground. A first attempt at rigorously assessing the impacts of shrimp farming on rural inhabitants is therefore attempted.

Three questions are often raised with respect to the social impacts allegedly caused by brackishwater shrimp aquaculture. First, what exactly are the social and environmental impacts affecting a particular shrimp farming region? A major portion of the literature available on this subject tends to focus on attempting answers to this first question. Nonetheless, the social impacts of brackishwater shrimp aquaculture are sparsely documented. Second, which impacts are considered more problematic for a specific village or in a particular shrimp farming region? The evidence amassed to answer this question is anecdotal at best. Our survey asked inhabitants of each village to rank each impact by severity. From this data an aggregate village rank was assessed and used to compare and contrast with other villages in the sample. Third, specifically, what are the determinants of the social impacts faced by a particular village community? To date, no empirical study has rigorously investigated this phenomenon. This is a result of the general unavailability of secondary data and the time consuming nature of generating a primary data set.

The answers to these questions are important as they enable policy makers to seek ways in which to minimise severe social impacts through a number of regulatory schemes. Equally important, however are the methods used to analyse and model the survey data. Chapter Seven and Chapter Eight attempt to provide rigorous answers to each of the three questions raised, with regard to coastal inhabitants of the Kandaleru region in Nellore District, Andhra Pradesh.

Specifically, Chapter Seven surveys the social and environmental impacts of brackishwater shrimp aquaculture facing rural inhabitants of the Kandaleru region. Each impact is identified through a primary survey of populations in twenty-six villages located adjacent to shrimp farming clusters. Moreover, each one is assessed by evaluating the rank order of impact severity. Chapter Eight, in contrast identifies the *determinants* of social impacts faced by village populations in the Kandaleru Region. This chapter reveals that village occupation and village location play an important role in defining the types of impacts faced by villages. Sea-based fishing villages are less likely than inland farming communities to face agricultural land salinity and fuelwood collection problems. They are, however, adversely affected by blocked access to the Bay of Bengal. Similarly, village socio-economic and demographic differences are important factors in explaining the existence and relative severity of social impacts. Moreover, structural characteristics of shrimp farming clusters such as their distance to the closest village and their total size are highly significant in explaining the degree to which social impacts adversely affect the well-being of communities located adjacent to shrimp farms.

By identifying the existence of different social impacts facing rural inhabitants and by assessing their relative severity, policy makers stand in good position to sensibly discuss the negative externalities arising from shrimp farming. In identifying the determinants of these impacts, it is possible for them to begin formulating solutions to ameliorate shrimp farming's negative social impacts. However, effective policy is often limited by the methods used to analyse data and interpret results. This is particularly known to be true of rank ordered data such as that collected in our 26 village survey. The methodological overview presented below summarises the relevant literature used to model and measure impact severity.

A Review of the Methodological Literature

The literature is rich with methods to analyse and model rank data. Ranking is an integral part of both non-parametric analysis and in the analysis of judges' rankings of objects (Marden, 1995). The literature is abundant with papers addressing fundamental questions such as, How to best elicit rankings? What goes on in a ranker's mind? How does one analyse such highly structured data? Some seminal works in the field include the Luce (1959) investigation of individual choice behaviour, the Arrow (1963) investigation of social choice and individual values, and the Coombs (1964) exploration of ordered data. Critchlow (1985) suggests methods with which to analyse partially ranked data. Diaconis (1988) presents a wealth of insights on modelling and ranking data collected from several different types of survey instruments.

The final two chapters of this dissertation are concerned with assessing impact severity based on preference ranking of social impacts. Following the pioneering work of Thurstone (1927), the basic unit of analysis consists of *n* individuals or judges ranking a set of *M* objects, or in our case, impacts. The set of impacts is denoted by $I = \{ I_1, I_1, \ldots, I_M \}$. A full *ranking* of the impacts assigns a complete ordering to the impacts: There is an impact that is most problematic, second most problematic, ..., and finally, least problematic. A rank vector lists the ranks given to the impacts, where "1" denotes most problematic and "M" denotes least problematic. An order vector lists the impacts themselves, in order from most problematic to least problematic. The question remains, what information can be extracted from such ranked data?

Rank data are multivariate data where the impacts represent the variables. Therefore, any multivariate method can be applied to rank data (i.e. means, standard deviations, histograms, cluster analysis, factor analysis, etc.). Rank data, however, have a natural structure that present additional challenges that those typically known in basic multivariate samples. For example, the distance between any two consecutive ranks is the same.[2] An entire sub-field within the

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[2] See Marden (1995) for a comprehensive overview of rank models addressing the issue of distance.

literature specialises in analysing the relationship between rank data and distance between the ranks (see Diaconis (1988) and Critchlow (1985) for an extensive discussion).

While basic statistical explorations of the data help describe the preferences of the population examined, formal modelling of the data can provide a deeper understanding (Marden, 1995:110). Models on ranked data arise from theoretical constructs, experimental methods, and others from attempts to find a simple description of the population of rankers. However, according to Marden (1995:3), "many of the models [in this field] are built, either on purpose or by happenstance." Two different approaches have been developed in the literature over the years, (i) a method to model the ranking process itself, and (ii) a data-analytic modelling approach to describe parametrically the distribution of rankings attached to a population of judges. Multi-dementional scaling models are abundant in the first approach. Most of these models such as those of Plackett (1975), Henery (1981) and Flinger and Verducci (1988) posit relationships between objects and judges, usually represented in some defined space. One well known axiom is that the closer a judge is to an object, the more preferred is the object (Coombs, 1964; Luce, 1959).[3] In contrast to the first approach which attempts to explain how judges perform their ranking, the second approach takes the rankings as the variables to be explained by explanatory variables that describe the population of judges. Marden (1995:112) suggests that utilising both approaches has several well known benefits:

- Theory-based models can be fit and tested;
- Main features of the data can be revealed;
- Significance testing reveals whether hypothesised relationships in the model are actually there;
- goodness-of-fit testing helps determine whether there may be additional relationships not originally hypothesised.

Both methods are employed in this investigation of social impacts. A model to describe the ranking process is developed in Chapter Seven, while the data-

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[3] This is empirically found to hold in Chapter 8 assessment of the determinants of shrimp farming's social impacts.

analytic model to examine the determinants of ranks is constructed and estimated in Chapter Eight.

Chapter 7
An Empirical Investigation of the Social Impacts of Shrimp Farming in South-eastern India

7.0 Introduction

Recently, shrimp farming has been creating concern over its degradation of the environment and its marginalization of local inhabitants from coastal resources. The markets have yet to incorporate the environmental and social costs associated with the rapid growth and development of brackishwater shrimp farming in India's maritime states. Instead, the environmental and social costs associated with this sector's negative externalities often fall on coastal inhabitants, who rely on natural coastal resources for their livelihood.

While the environmental consequences of shrimp farming are becoming more well known as a result of a growing body of scientific research, the social impacts of shrimp farming are less well known. For example, there are several experimental stations in the United States, United Kingdom, Europe and Southeast Asia examining how a brackishwater body's natural carrying capacity can be breached as a result of intensive shrimp farming. Experiments on the aquatic environment are conducted in controlled scientific settings. Thus, it is possible to distinguish those culturing methods that are more environmentally friendly from those that are not. The same, however, cannot be said about social impacts allegedly caused by shrimp farming.

The distinction between social impacts and other impacts (i.e. environmental) of shrimp farming is often blurred (Hempel & Winther, 1997:61). Claridge (1996) for example suggests that decreased production of fish and other food resources, displacement of labour, credit monopoly by big business houses, concentration of land ownership with speculators and indebtedness as a result of abandoned farming areas constitute a few of the many social impacts possible as a result of a growing shrimp farming sector. Generally, social impacts of shrimp farming arise as a result of a redistribution of wealth, restricted access to traditionally open access areas, conflict arising as a result of competition for natural resources, human rights violations, and many others.

Several social impacts were cited in the documentation leading to the Indian Supreme Court (SC) ban of the shrimp farming sector in India. They include, well water salinity and desertification of cultivable land as a result of salt water intrusion; loss of grazing grounds for cattle; destruction of mangrove forest areas; manpower loss as a result of blocked access of fishermen to the sea shore; rising incidences of skin and eye irritations and water borne diseases (Supreme Court Notification, 1996:184). However, the proof underscoring each allegation remains anecdotal or based on personal observation of investigative teams commissioned by the SC.

This research attempts to analyse the extent of shrimp farming's social impacts on coastal communities located in the Kandaleru region by analysing and modelling rank data. This is accomplished in eight sections. Section 7.1 presents an overview of the primary data used in the empirical investigation. Section 7.2 identifies the social impacts faced by fishing and farming communities and those villages located adjacent to sea-based and creek-based shrimp farms. Section 7.3 discusses how each negative social impact reduces the well-being of Kandaleru inhabitants. It also investigates the relative importance placed on each impact by examining the mean rank of each impact. Section 7.4 presents a method with which to measure the severity of social impacts in the region. Section 7.5 assesses the severity of social impacts facing villages in the Kandaleru region. Section 7.6 concludes with some discussion on the usefulness of the social impact index as a measure for severity.

7.1 The Data

A pre-tested survey identified the major impacts of the brackishwater shrimp aquaculture sector on the welfare of village populations located adjacent to shrimp farming clusters in Nellore District. As discussed in Chapter 2, several questions adopted for the survey were raised recently by NGOs and other concerned organisations in Indian and international forums. The overarching concerns stemmed from alleged negative impacts of the rapidly expanding brackishwater shrimp aquaculture industry on rural communities. In total, 26 villages were surveyed and asked six principal questions regarding shrimp aquaculture development:

- Has aquaculture development hindered your (your family's) access to the creek or beach?
- Have your village wells become saline as a result of shrimp farm development?
- Has aquaculture development resulted in seepage of saline water into your agricultural lands? Has this reduced your crop yields?
- Has aquaculture development led to unemployment problems for you or your family?
- Has aquaculture development led to health problems for you or your family? to animal populations in the village?
- Has aquaculture development hindered fuelwood or fodder collection for your family?

The survey was conducted in two parts. First, each respondent was asked to answer each of the above questions by answering "Yes" or "No". From these data it was possible to determine each impact's frequency of occurrence within a village.[1] Second, each respondent was asked to rank the above mentioned impacts according to the relative severity of the social impact on their daily lives: 1 (most severe problem) to 6 (least severe problem). From these data, an aggregate rank order for each impact is calculated using the well known Thurstonian (1927) method.[2] The results presented throughout this chapter are based on these aggregate ranks.

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[1] The method used to aggregate village responses to assess an impact's frequency of occurrence is presented in Appendix 7A.

[2] The Thurstonian (1927) method is briefly outlined in the Part III summary of this dissertation. For an overview of this method and related methods, see Marden (1995:114-118).

7.2 Identification of Social Impacts

In this section we answer the first question raised in the literature, namely, what are the social impacts of shrimp farming on rural inhabitants of the Kandaleru region?

The survey results indicate that for the entire sample of twenty-six coastal villages, nineteen villages or 73% identified agricultural land salinity and blocked access to the creek/beach as a problem in their village; seventeen or 66% of the villages reported that well water salinity was a problem in their village; fourteen villages or 54% identified unemployment as a problem; ten villages or 38% reported fodder & fuelwood collection as a problem; and nine villages or 35% identified health problems as a result of aquaculture development as a problem.[3]

Aggregated data for all twenty-six villages, however present a distorted picture of the problems faced by the region's villages. The principal occupation of a village and its location are found to be important determinants of social impacts. Table 7.0 shows that 94% of those villages comprised of fishers identified blocked beach access as a problem whereas only 33% of farming based villages identified access as a problem. Similarly, unemployment and health problems affect a majority of the fishing community, 76% and 53% respectively but only one of the farming villages. Approximately 89% of farming communities identified fodder & fuelwood collection as a problem whereas only 12% of the fishing communities did so. Well water salinity, however remained a problem for both 66% of fishing and farming village communities.

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[3] A particular village is counted among those sample villages claiming to suffer from a given social impact if greater than 50 percent of the village population sampled identified it to be a problem facing them or their family. The methodology used to calculate the aggregate frequencies presented in Table 7.0 and throughout this section is presented in Appendix 7A, section 7A.0. Some intermediate data needed to calculate aggregate frequencies are presented in Appendix B.

Table 7.0
Problems Identified by Communities Located Adjacent to Shrimp Farms in the Kandaleru Region, Nellore District, Andhra Pradesh.

% Villages w/ Problems (N=26 Total Villages)	*Well Water Salinity*	*Access to Beach or Creek Blocked*	*Agricultural Land Salinity*	*Un/under employment*	*Poor Health*	*Fodder & Fuelwood*
Fishing Villages (N=17)	65% (11)	94% (16)	65% (11)	76% (13)	53% (9)	12% (2)
Farming Villages (N=9)	66% (6)	33% (3)	89% (8)	11% (1)	0% (0)	89% (8)
Sea-Based Villages (N=16)	63% (10)	88% (14)	75% (12)	81% (13)	56% (9)	0% (0)
Creek-Based Village (N=10)	70% (7)	50% (5)	70% (7)	10% (1)	0% (0)	100% (10)
All Villages (N=26)	65% (17)	73% (19)	73% (19)	54% (14)	35% (9)	38% (10)

source of data: Patil & Village Survey, 1997

The survey data reveal that 94 percent of all fishing villages in the sample are sea-based villages and that 90 percent of the creek-based villages are primarily engaged in agriculture. The impacts faced by villages categorised by location are therefore similar to those categorised by occupation. However, making this distinction reveals two important findings. First, of the two fishing and eight farming villages complaining of fodder and fuelwood collection problems, all of them are located adjacent to creek-based farms. Second, each of the nine villages suffering from health problems are sea-based villages. In fact, beach/creek access and unemployment are also separated along occupational and locational lines. We can hypothesise, therefore that social impacts have something to do with geographic location and a village's primary occupation. The determinants of the social impacts discussed above are assessed and further discussed in the next chapter.

Finally, in response to the December 1996 Indian Supreme Court order banning the shrimp farming sector, only two of the ten creek-based villages reported that they were in favour of it. Of these two villages, one reported that they were *worse off* than five years ago and the other reported that they were neither better or worse off than before. Four villages reported that they were not in favour of the ban and the remaining four villages were indifferent (see Chapter 2). The primary village survey conducted for this research identifies the primary social impacts facing sample villages. It does not, however, reveal the relative *severity* of each impact on coastal inhabitants. The severity of each impact is discussed in context of how the rural population perceive each social impact's impact on their economic activity and overall village welfare.

7.2.1 Ranking Social Impacts by Frequency

Indian policy makers are concerned with prioritising the importance of impacts facing rural communities (SC Notification, 1996). The Indian SC notification and subsequent discussion made it clear that some impacts were somehow more important than others.[4] In Table 7.1 each impact is ranked by the reported frequency of its occurrence amongst sample farming and fishing villages. A rank of "1" for the fishing village category in Table 7.1, for example, corresponds to the highest impact frequency for fishing villages, namely, blocked access (see Table 7.0). The ranked frequencies for the entire Kandaleru village sample is presented in the final column of Table 7.1.

Table 7.1
Social Impacts Ranked by Frequency

Ranked Impacts	Fishing Villages Rank	Farming Villages Rank	All Villages Aggregate Rank
Well water salinity	3 or 4	3	3
Blocked access	1	4	1 or 2
Agricultural land salinity	3 or 4	1 or 2	1 or 2
Un/under-employment	2	5	4
Poor health	5	6	6
Fodder & fuelwood	6	1 or 2	5

note: a rank of "3 or 4" indicates that the corresponding impact shares the same frequency as another with the same frequency.

The rank order and the frequency itself illustrate that the six social impacts face villages categorised by occupation, differently.[5] This suggests that the policy objective may be different and based on occupational groups and/or location when considering methods to minimise social impacts.

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[4] This issues has been taken up by the Aquaculture Authority of India created through the 1997 Aquaculture Authority Act in March 1997.

[5] The same rank order arose when villages were categorised by location.

7.3 Impact on Economic Activity

While the previous section identifies the social impacts most common to fishing and farming communities and those located adjacent to sea-based and creek-based farms, it does not explicitly indicate the relative importance of each social impact as perceived by each village and the sample villages in aggregate. The relative importance of an impact can be assessed based on how much each impact reduces the overall well-being of the Kandaleru community. For example, while 73 percent of the village sample indicate that blocked access to the sea or creek is a problem facing their village, it may be of less overall consequence than for the 38 percent that suffer from problems of ill health. This may hold true since the overall welfare loss as a result of health may be greater than that of blocked access. The frequency of a particular problem arising amongst the sample villages is therefore not an adequate measure of its overall severity. However, an exact measure of the "costs" assumed by the village as a result of facing a social impact is not attempted in this research. Nonetheless, a method to measure the relative importance of each social problem in terms of its impact on the community is of interest.

Each of the social problems identified in the previous section has an associated impact on the economic activity taking place within the village community. The literature is abundant with methods with which to measure the severity of the impact in terms of its economic loss.[6] For example, an increase in the amount of *time* required to carry out a particular economic activity may ultimately reduce the overall productivity of the community. Similarly, the loss of a necessary resource such as potable water has significant consequences on the welfare of a community. The loss of a resource can be valued based on its replacement cost or shadow price.[7] However, data necessary to carry out such assessments in this research is lacking. A different approach is therefore needed.

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[6] See Pearce and Turner (1990) for a review of several methods used to evaluate the loss of an environmental resource or a decline in economic activity as a result of externalities.

[7] Pioneering contributions on shadow price assessments are attributed to Arrow and Fisher (1974). See Dasgupta (1993) for a discussion of this issue with respect to a decline in a natural resource stock.

This section examines how each social impact can translate into a direct welfare loss for village communities in the sample.[8] However, unlike much of the environmental economic literature that attempts to value the economic costs of each social impact, this research explores how the affected communities *perceive* the severity of facing particular impacts relative to the others. Clark and Oswald (1996) suggest that subjective data such as these are often strong predictors of reality. In this context, the ranked data analysed in this section provide a simple indication of the importance of each of these social impacts on the well-being of rural inhabitants relative to each other.

Table 7.2 presents some summary statistics on the aggregate mean rank score assigned to each social impact for the 17 fishing villages, the 9 farming villages and the entire 26 village sample, respectively. The method used to assess the rank order for each impact in each of the sample 26 villages is discussed in Appendix 7A, section 7A.1. The method used to assign the aggregate rank order for each impact and used to construct Table 7.2 is simply the average of each aggregate village response for a given impact (see Appendix A, section 7A.2).

Comparing the means of the individual village ranks is one method of assessing the relative importance of each social impact in the sample. However, it is clear that the mean rank of the 26 village sample is skewed by the large sample size of fishing villages. Nonetheless, the ensuing discussion is based on the results presented in the table below and informal discussion with inhabitants of both fishing and farming villages.[9]

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[8] The thesis does not attempt to value each social impact. Valuation of social impacts requires much more detailed data which were not collected as part of this study. It is therefore beyond the scope of this particular analysis.

[9] See Table 7B.1 in Appendix 7B for summary ranks for villages categorised by location.

Table 7.2
Summary Characteristics of Ranked Impact Data

Impact	Mean Rank	S.D.	Minimum	Maximum
17 Fishing Villages				
WWSALIN	2.41	1.37	1	5
ACCESS	1.58	0.87	1	4
AGSALIN	3.12	1.16	1	5
UNEMPL	3.71	1.04	1	5
HEALTH	4.59	0.39	3	6
FODFUEL	5.65	0.99	3	6
9 Farming Villages				
WWSALIN	2.78	0.83	2	4
ACCESS	2.67	1.22	1	4
AGSALIN	2.44	1.13	1	4
UNEMPL	4.56	1.33	1	5
HEALTH	5.89	0.33	5	6
FODFUEL	2.33	1.80	1	6
26 Village Sample				
WWSALIN	2.54	1.21	1	5
ACCESS	1.96	1.11	1	4
AGSALIN	2.88	1.17	1	5
UNEMPL	4.00	1.20	1	5
HEALTH	5.03	0.99	3	6
FODFUEL	4.50	2.06	1	6

source of data: Patil & Village Survey, 1997. **Note:** wwsalin is well water salinity; access is blocked access; agsalin in agricultural land salinity; unempl is unemployment; health is health related problems, foduel is fodder and fuelwood collection problems. The mean values range from 1 (most severe impact in relation to the others) to 6 (least severe impact relative to the others).

(i) Blocked Access

Blocked access has the lowest mean score of the six social impacts for the 26 village sample. It can be said to be the most important impact faced by the sample village's surveyed in the region. For fishers, in particular, blocked access is the most significant impact they face. Since the advent of shrimp farming, fishers claim to require more time and energy to gain access to their boats which are kept on the beach (SC Notification, 1996). Previously, fishers had a direct path to their fishing crafts. With shrimp farms situated between fishing villages and the beach and occupying several dozen hectares of land, direct access between the beach and the village has been blocked. This has had several other implications such as a longer and more difficult transport route of fish catch to the local village market. According to semi-formal discussions with female fishers, this was of particular concern to women. For farming and creek-based communities, blocked access is the third most significant impact they face, albeit for different reasons than for fishers. Discussions with inhabitants of farming communities suggested that blocked access to the Kandaleru creek was problematic since areas traditionally used to collect fodder and fuelwood were blocked.

(ii) Fodder & Fuelwood Collection Problems

A mean score of 2.33 suggests that farming villages identified fodder and fuelwood collection problems as the most problematic impact they face. The demands on village females' daily chores are strained as a result of fodder & fuelwood collection problems. Semi-structured interviews suggest that in farming communities, women spend more time searching for cooking fuel and fodder to feed their animals. They indicated that this was a result of the growing number of shrimp farms occupying wasteland once used to graze animals and collect fuelwood. With the growth of the shrimp farming sector along the Kandaleru river, large areas of thorny bushes (used as a source of fuelwood) were cleared. These problems are of little importance to sea-based communities. In fact, each of the sixteen sea-based villages ranked collection problems as the least important impact that they face.[10] This is as a result of the geographic location of the sea-based villages. This is further discussed in the next chapter.

(iii) Well Water Salinity

According to the village survey, both sea and creek-based communities have experienced salinity problems with their drinking water supply. This is also confirmed by Rao (1996) who scientifically tests several dozen village wells in the Kandaleru region and reveal that salinity concentrations were higher than the acceptable limit. The mean rank for water salinity given by sea-based and creek-based villages in our sample is 2.56 and 2.50, respectively. Therefore, based on

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[10] See Appendix 7B.

the mean score, well water salinity is the second most important impact facing villages in each location.

The salinity levels of village well water are reportedly rising as a result of saline pond water seeping through the pond bottom and into groundwater reservoirs from which village tube wells draw their water (Joseph, 1996). The force of this impact falls on women who are usually in charge of water collection for the household. In many cases, less than fifty percent of the village wells were left idle as a result of salinity problems.[11] In extreme cases where all the village wells were contaminated, women were required to walk up to two kilometres to fetch potable water from the nearest uncontaminated well. It appears, however, that well water salinity is seasonal and related to the intensity of the monsoon season.[12]

(iv) Agricultural Land Salinity

Salinity of agricultural land is another problem faced by both farming communities involved primarily in agricultural production and some fishing communities that rely on the productivity of small vegetable plots for private own consumption. Approximately 90 percent of the farming villages in the sample complained of land salinity and specifically, falling paddy, casuarian and small vegetable crop yields on plots directly adjacent to shrimp farms. The overall mean rank of this impact 2.88, which makes it the third most important social impact facing Kandaleru villages.

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[11] We observed that most of the wells that the village population indicated as useless were located nearest to shrimp farms. However, while salinity of well water may be determined partly by distance, scientific studies have indicated that geography and characteristics of the underground aquifer are important determinants of salinity (see Joseph, 1996).

[12] An extended monsoon period tends to dilute the village well salinity level to tolerable limits. To me, village wells which were identified as never having been contaminated were salty. We suggest that there is a thresh-hold of acceptable water salinity levels that varies among villages in the region, but do not explore this further.

(v) Unemployment and/or Underemployment

Employment issues tend to affect fishing communities much more than farming communities. Although shrimp farms continue to hire a steady stream of rural inhabitants for seasonal employment, inhabitants of sea-based fishing villages complain that the direct purchase of wild seed has declined rapidly over the past year. This is most likely a direct result of the growth of operational seed hatcheries in the nearby vicinity.[13] Whereas shrimp farms in the region once relied solely on wild caught seed purchased from fishers, with the growth and development of hatcheries, farms have a steady supply of seed at a rate that depends on quantity purchased as opposed to per individual seed. The result is that once informally employed seed collectors are now out of work.

(vi) Poor Health

Finally, fishers' productivity and general well being are also affected by health related problems caused by shrimp farm effluent discharge from jetties into the near shore area where they fish.[14] In addition, they complain that their nets get cut by the effluent discharge pipes that extend up to fifty meters into the sea. Creek-based farming villages unanimously ranked this problem as the least important of the six impacts. The mean rank of fishing villages, however is 4.59, which suggests that it is of some concern.

7.3.1 Ranking Social Impacts by Mean Score

Each impact is ranked by the mean of the ranked data assessed in the previous section. The social impact with the lowest average mean can be thought of as the most problematic impact facing that occupational group. This is possible since each impact is assigned a rank between one and six based on the responses given by populations in each village in the sample. Even though a

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[13] These issues are discussed in greater detail in Chapters 3 and 4.

[14] Shrimp farm effluent is known to be contaminated from excessive biological and chemical inputs used in production.

majority of the village claim that they do not suffer from, say two of the six impacts, these last two impacts are still ranked relative to each other based on the relative frequencies as discussed in Appendix A, section 7A.1. Table 7.3 presents the order of rank for impacts assessed by mean score.

Table 7.3
Social Impacts Ranked by Mean Score

Ranked Impacts	Fishing Villages Rank	Farming Villages Rank	All Villages Aggregate Rank
Well water salinity	2	4	2
Blocked access	1	3	1
Agricultural land salinity	3	2	3
Un/under-employment	4	5	4
Poor health	5	6	5
Fodder & fuelwood	6	1	6

note: a rank of "1" indicates that this impact on average is the most important facing the category.

It is clear that social impacts can translate into a direct welfare loss for village communities in the sample. The mean of the ranked data (Table 7.2) and the assigned rank for each social impact (Table 7.3) provide some indication of the relative importance of each of these social impacts on the well-being of rural inhabitants. It does not, however, indicate the absolute severity of these impacts on inhabitants of the Kandaleru region. The next several sections suggest one way in which the ranked impact data can be translated into a severity index.

7.4 Assessing the Severity of Social Impacts

The six major negative impacts common to most villages in the Kandaleru region as a result of the growth and development of shrimp farming in the region are well water salinity, blocked access to the creek or beach, agricultural land salinity, unemployment and underemployment problems, health problems, and fodder and fuelwood collection problems. At this stage, it is not possible to adequately determine the extent to which each impact distresses Kandaleru inhabitants. Previously, section 7.1 identified social impacts faced by different communities and the number of villages in the sample that claim to find that particular negative eternality a problem. Moreover, section 7.2 discussed how each negative impact reduces the well-being of Kandaleru communities. The mean rank provided a simple indication of the degree to which each impact is problematic. Neither of these, however, explicitly measure the *severity* of social impacts. Together, however, these data provide necessary information to construct an index of impact severity.

This section develops an index with which to assess the severity of social impacts, given the data collected using the village survey. The Social Impact Index (SII) is constructed and applied to sample village data to discover the *severity* of each social impact on (i) villages categorised by a particular occupation or location; and (ii) the entire village sample. It requires use of data identifying both the frequency of a particular problem existing amongst sample villages and the relative rank order assigned to each impact.

7.4.1 Social Impact Index

The severity of a given impact is the weighted average of the relative ranking of each social impact problem for each village, scaled by a parameter that weights the index by the number of villages reporting that particular impact as disruptive to their general well-being. More formally, the Social Impact Index of an impact i faced by village n belonging to category k is defined as,

$$(1) \qquad SII_i^k = \frac{\sum_1^N (A_i^{n,k} r_i^{n,k})}{(\sum_1^N A_i^{n,k})^\theta} \qquad n=1,2,3,\ldots,N; \; i = 1,2,\ldots M$$

where N is the total number of villages surveyed. M is the total number of impacts identified as posing a problem in the region. K is the total number of categories by which we can organise the sample villages. $k \in (1,2,\ldots K)$.[15] $A_i^{n,k}$ is assigned a value of "1" or "0" according to its given properties (see Appendix 7A, section 7A.0 for the method used to assign $A_i^{n,k}$ its value). Essentially, if the aggregated village response reveals that impact i is not a problem facing village

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[15] For example, we set $k=1$ if the principal occupation in the village is fishing and $k=2$ if the principal occupation in the village is farming. In this example, K=2. If we wanted to analyse the

n, then $A_i^{n,k} = 0$. In contrast, if the aggregated village response reveals that impact i is indeed a problem facing village n, then $A_i^{n,k} = 1$. Special properties for the case when (1) is undefined are presented in Section 7.4.4.

$r_i^{n,k}$ is the rank order assigned by village n categorised by k to impact i relative each of the other M social impacts and bounded by, $1 \leq r_i^{n,k} \leq S$, where S is the numerical rank order identifying the least disruptive social impact relative to the others. The numerical value of S is equal to M. $r_i^{n,k}$ can therefore be thought of as the degree to which impact i is disruptive to the well-being of village n *relative* to each of the other social impacts. If impact i is found to be the most problematic social impact facing village, then $r_i^{n,k}=1$. By contrast, if impact i is the least problematic social impact facing village n, then $r_i^{n,k} = \mathrm{S}$. The method used to assign values to $r_i^{n,k}$ is presented in Appendix 7A, section 7.A1.

The numerator in (1) is interpreted as the sum of the relative rank orders of impact i assigned by all N villages if and only if impact i is found to disrupt village n (i.e. $A_i^{n,k} = 1$). The denominator in (1) is comprised of (i) a weight, $\sum_{1}^{N} A_i^{n,k}$ which counts the number of villages in each category k that responds such that $A_i^{n,k} = 1$; and (ii) an exponent θ which serves as an exponential scaling parameter that takes a numerical value such that $1 \leq \theta \leq E$ and $\theta \in (1,2,\ldots E)$.

It therefore serves as a mechanism to give greater weight to a given social impact for which a greater number of villages reported it as disruptive to their well-being. It is bounded such that $1 \leq \theta \leq E$ and defined such that $\theta \in (1,2,\ldots E)$. If $\theta = 1$, then the expression in (1) reduces to a simple average of the relative rank orders assigned by each village for a particular social impact, i. As $\theta \to E$, the expression in (1) gives greater importance to the number of villages responding that an impact is problematic in their village, $A_i^{n,k} = 1$. In the empirical estimation of (1) discussed in Section 7.5 of this chapter, $\theta = 2$. A simulation experiment on the SII for different values of θ is conducted in

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SII for villages categorised by geographical location from the sea (i.e. North, South, and West), then we could define k=1 (North), k=2 (South) and k=3 (West). In this example, K=3.

Appendix 7F. The results of the simulation experiments help justify the inclusion of *theta* as a component in the index and justify the value assigned it.

7.4.2 The Aggregate Social Impact Index

As discussed above, the Social Impact Index (SII) of impact *i* defined in (1) is the weighted average of the relative ranking of each social impact problem for villages of category, *k* and scaled by an exponent of the number of villages reporting that particular impact as disruptive to their general well-being. Next, an aggregate social impact index across all K categories is constructed. The aggregate social impact index of an impact *i* faced by all N villages belonging to one of *K* categories is defined as,

$$\text{SII}_\text{i} = \frac{1}{K}\sum SII_i^k = \frac{1}{K}\sum_1^K \left(\frac{\sum_1^N (A_i^{n,k} r_i^{n,k})}{(\sum_1^N A_i^{n,k})^\theta}\right) \tag{2}$$

$i=1,2,3,\ldots,N;\ i = 1,2,\ldots M;\ k = 1,2,3,\ldots K.$

where SII_i is the aggregated Social Impact Index for impact i. It is weighted by the size of category *k* and scaled by the number of villages positively identifying impact *i* as a problem. The Sample Social Impact Index in (2) is essentially an average of the social impact indices over all K categories. Each of the K categories are given equal weight. All variables and parameters in (2) are as previously defined.

There is a significant difference between the index values obtained from (2) and the results obtained from simply taking the average of the Social Impacts Indices across all N villages. The SII as defined in (2) gives equal weight to each *k* category.[16] An average of the SII for a given impact across all *n* villages would unnecessarily give greater emphasis to the category *k* with the greater number of villages. We suggest that each of the K categories be given the same weight despite the possibility of an unequal number of villages in each category. We

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[16] We define SII (with no superscripts or subscripts) as the generic Social Impact Index which can refer to either SII_i^k or SII_i.

choose this approach under the assumption that each of the K categories are of equal importance.[17]

7.4.3 A Justification for θ

As discussed earlier, θ serves as an exponential scaling parameter that takes a numerical value such that $1 \leq \theta \leq E$ and where $\theta \in (1,2,\ldots E)$. It serves as a mechanism to give greater weight to a given social impact for which a greater number of villages reported it as disruptive to their well-being. It is bounded such that $1 \leq \theta \leq E$. As $\theta \to E$, the expression in (1) gives greater importance to the number of villages responding that an impact is problematic in their village, $A_i^{n,k} = 1$. A simulation experiment on the SII for different values of θ is conducted in Appendix 7E. The results of the simulation experiments help justify the inclusion of *theta* as a component in the index and justify the value assigned to it in empirical application (in the empirical estimation of (1) discussed in Section 7.5 of this chapter, $\theta = 2$). It is clear that the value taken by θ clearly matters.

7.4.4 A Property of the Social Impact Index

There are several important theoretical properties of the Social Impact Index worth noting. The first property arises from the result that (1) and (2) are undefined when $\sum_{1}^{N} A_i^{n,k} = 0$, because division by zero is not possible. To eliminate this complication from the model we introduce the following proposition:

Proposition 1:

If $\sum_{i}^{N} A_i^{n,k} = 0$ for any impact *i* we then define,

(3) $$SII_i^k = \max SII_i^k + \tfrac{1}{M}(\max SII_i^k) \quad \textit{for any i.}$$

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[17] Some caveats and assumptions made regarding the SII are presented in Appendix 7D.

where $\max SII_i^k$ is the maximum numerical value of the Social Impact Index for any impact *i.* The expression in (3) ensures that an impact identified as not being a problem for all villages in a particular category receives a numerical value higher by a factor, $\frac{1}{M}(\max SII_i^k)$ than the highest calculated SII value. This ensures that if there is a case such that $\sum_i^N A_i^{n,k} = 0$ for all *n*, then the SII for impact *i* is not undefined and that the impact *i* receives the lowest ranking of all *M* impacts, namely, *S.* By introducing (3), the model as described by (1) and (2) becomes operational.

7.4.5 Evaluating Boundary Conditions of the SII

L'Hopital's rule is employed to evaluate the Social Impact Index at its extreme values. Generally, L'Hopital's rule evaluates the limit of the function, $f(x) = \frac{m(x)}{n(x)}$ as $x \to a$ (where a can be either finite or infinite), when the numerator *m(x)* and the denominator *n(x)* either (1) both tend to zero as $x \to a$, thus resulting in the *0/0* form, or (2) both tend to $\pm\infty$ as $x \to a$, thus resulting in an expression in the form of $^{\pm\infty}/_{\pm\infty}$.

Even though the limit cannot be evaluated in these cases, its value can be determined by taking the first derivative of the function and evaluating the *limit* as $x \to a$,

[L'Hopital's Rule] $$\lim_{x \to a} \frac{m(x)}{n(x)} = \lim_{x \to a} \frac{m'(x)}{n'(x)}$$

In order to evaluate the SII at its theoretical boundaries, we define $m(x) = \sum_1^N (A_i^{n,k} r_i^{n,k})$ and $n(x) = (\sum_1^N A_i^{n,k})^\theta$. Following L'Hopital's rule the limit of the functions represented in (1) and (2) are evaluated by first taking its derivative,

$$(4) \qquad \lim_{\sum_1^N A_i^{n,k} \to a} \frac{\sum_1^N (A_i^{n,k} r_i^{n,k})}{(\sum_1^N A_i^{n,k})^{\theta}} = \lim_{\sum_1^N A_i^{n,k} \to a} \frac{1}{\theta(\sum_1^N A_i^{n,k})^{\theta-1}}$$

Next, the expression in (4) is evaluated as a tends to its extremes, namely $a=0$ such that, (i) $\sum_i^N A_i^{n,k} \to 0$; and $a = \infty$ such that, (ii) $\sum_1^N A_i^{n,k} \to \infty$. Under scenario (i) the limit of the function tends to infinity and under scenario (ii) the limit tends to zero.

7.4.6 Defining Social Impact Severity Classes

We have shown how the SII_i^k and the aggregate SII_i are constructed and how they can be used to rank the severity of each social impact faced by groups of villages. The SII can essentially index the *severity* of a given social impact on a particular category of village (i.e. fishing or farming) or the entire aggregated rural community sample. However, one problem remains. The numerical value of the Social Impact Index remains meaningless unless a scale is developed with which to interpret it. In this section we suggest one possible scale with which to interpret the *severity* of social impacts. This scale places the numerical value of each SII_i for all i into an Impact Severity Class (SC) which identifies the degree to which that particular social impact is disruptive to the well-being of a rural community.

We begin by defining a scaling system comprising of $J+1$ intervals bounded by two constructed cut-off points. We call each bounded interval a *Severity Class*. Severity Class j (*SC(j)*) is therefore the interval defined by,

$$(5) \qquad \frac{\max SII_i^k + \frac{1}{M}(\max SII_i^k)}{2^{j+1}} < SC(j) \leq \frac{\max SII_i^k + \frac{1}{M}(\max SII_i^k)}{2^j}$$

where $j=0,1,2,...J.$; M is the total number of social impacts under investigation; $SC(j)$ is the severity class within which impact i falls. There are three important properties associated with the Severity Class as defined in (5),

(i) The Number of Severity Classes

There are $J+1$ Severity Classes in total. The specific number of Severity Classes required is defined by restricting J+1=M. Theoretically, with this restriction, the number of severity classes has an upper limit of M and a lower limit of 1. In empirical application, however, we suggest that the maximum number of Severity Classes be restricted when $M \geq 10$ to $M/2$ and when M is an even number and $\frac{M+1}{2}$ when M is an odd number.[18]

(ii) Upper & Lower Bounds

From (5), $\max SII_i^k$ represents the Social Impact Index for any impact i with the highest numerical value; the expression,

$$\frac{\max SII_i^k + \frac{1}{M}(\max SII_i^k)}{2^j} \tag{6}$$

defines the lower bound of each and every severity class, $SC(j)$. The upper bound of the interval is defined by,

$$\frac{\max SII_i^k + \frac{1}{M}(\max SII_i^k)}{2^{j+1}} \tag{7}$$

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[18] The number of Severity Classes in some empirical studies may benefit from relaxing the strict rules suggested by the SII model. We suggest the restriction J+1=M as one possible rule to follow, but fully suggest that the restrictions vary depending on the nature of the research.

The expression, $\max SII_i^k + \frac{1}{M}(\max SII_i^k)$ ensures that any impact i for which none of the n villages defined by category k identify as a problem is not given a zero value, which would distort the SII and the eventual ranking of that impact.[19]

(iii) The Size of SC(j) Decreases with j

The denominator of (7) ensures that the numerator is scaled such that the size of each Severity Class decreases with j. Essentially, the interval defined by *SC(0)* is twice the size of the interval defined by *SC(1)*, which in turn is twice the size of the interval defined by *SC(2)*, etc. *SC(J)* is therefore bounded by the smallest interval defined by (5). This property ensures that the *most severe* social impacts are stringently classified.

(iv) A Special Case of (5)

In the special case where *Proposition 1* is evoked, the weak inequality ($\leq$) of the lower boundary for the lowest Severity Class, SC(0), is exchanged by the strong inequality ($<$). This ensures that the numerical value of the social impact i in question falls outside the specified severity classifications. In other words, this ensures that under this special case, the impact in question is not inappropriately classified.

(v) Interpreting SC(j)

The numerical value of SII falls within a Severity Class defined by (5) and is loosely interpreted using the conversion table below. Each Severity Class corresponds to the degree of severity faced by a village or group of villages for a given social impact. For example, if *M=6*, then we could identify six severity classes with the following corresponding conversion interpretation for each SC(j).

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[19] See Proposition 1 in Section 7.4.4.

Severity Class-Impact Intensity Conversion Table

Severity Class j	*Intensity of Social Impact*
j=5	social crisis
j=4	very severe
j=3	severe
j=2	moderate
j=1	problematic
j=0	nuisance

For J+1 greater than or less than six, the interpretation of each severity class will change from the second column suggested above. We can, however, restrict J+1=6 throughout without any significant loss to the interpretation of the empirical results. In fact, there may not be too much advantage gained from identifying more than six severity classes as interpretation of the results may become cumbersome.

(vi) A Caveat

The Impact Severity Classes defined above are only one possible way of evaluating the numerical value of the index. In addition, the "impact intensity" categorisations set out in the Severity Class-Impact Intensity Conversion Table are also discretionary. Nonetheless, it provides a first attempt at qualifying a numerical value defined to represent impact severity with respect to the data available.

7.5 An Empirical Application

This empirical examination measures the Social Impact Index for each known impact and assess the severity of each impact on rural inhabitants. The twenty-six villages in the Kandaleru sample are categorised by principal occupation, namely, fishing and farming villages. There are seventeen fishing villages and nine farming villages. In this investigation social impacts are measured for both fishing and farming villages separately before assessing the impact severity over the entire twenty-six village sample.

7.5.1 Measuring the Severity of Impacts Facing Kandaleru Villages

Following equation (1), the SII for each of the six social impacts affecting the welfare of inhabitants of seventeen fishing villages is,

$$(1.1)\quad SII_i^1 = \frac{\sum_{1}^{17}(A_i^{n,1} r_i^{n,1})}{(\sum_{1}^{17} A_i^{n,1})^2} \qquad n=1,2,3,\ldots,17;\ i=1,2,3,4,5,6;\ \ k=1;\ \theta=2$$

where the parameters are respectively, N=17, M=6, K=2 and E=2. The SII for each of the six social impacts attributed to the advent of shrimp farming for all nine farming villages in our sample is defined as,

$$(1.2)\quad SII_i^2 = \frac{\sum_{1}^{9}(A_i^{n,2} r_i^{n,2})}{(\sum_{1}^{9} A_i^{n,2})^2} \qquad n=1,2,3,\ldots,9;\ i=1,2,3,4,5,6;\ \ k=2;\ \theta=2$$

where the parameters are as defined in (1.1) with the exception of $N=9$ and $k=2$. The severity of social impacts facing the Kandaleru region is represented as,

$$(2.1)\quad \mathrm{SII}_i = \frac{1}{2}\left(\frac{\sum_{1}^{17}(A_i^{n,k=1} r_i^{n,k=1})}{(\sum_{1}^{9} A_i^{n,k=1})^2} + \frac{\sum_{1}^{9}(A_i^{n,k=2} r_i^{n,k=2})}{(\sum_{1}^{9} A_i^{n,k=2})^2}\right) \qquad i=1,2,\ldots 6;\ K=2$$

with $k=1$ indicating that the village is a fishing village and $k=2$ indicating that the village is a farming village, $\theta=2$ and all other variables as previously defined. Table 7.4 presents the results.

Table 7.4
Social Impact Indices by Villages' Primary Occupation

SII INDEX	Well Water Salinity	Blocked Access	Agricultural Land Salinity	Un/under employment	Poor Health	Fodder & Fuelwood
Fishing Villages (N=17)	0.149 (11)	0.090 (16)	0.248 (11)	0.272 (13)	0.440 (9)	0.750 (2)
Farming Villages (N=9)	0.471 (6)	0.443 (3)	0.281 (8)	1.00 (1)	1.75* (0)	0.235 (8)
All Villages (N=26)	0.310 (17)	0.266 (19)	0.264 (19)	0.636 (14)	1.22 (9)	0.675 (10)

source of data: Patil & Krishnan, 1997; note: the number of villages in parenthesis; *represents the special case discussed in (iv) of section 7.4.6. The numerical SII value is therefore determined evoking proposition 1 from 7.4.4. Note: A smaller number (closer to zero) indicates that the particular social impact is more severe for villages of a given category.

7.5.2 Assessing the Severity of Social Impacts

As previously discussed in sub-section 7.4.6, the Social Impact Index is a numerical value that falls into one of *J+1* Severity Classes defined by (5) and that can be interpreted using the scaling factor outlined in the *Severity Class-Impact Intensity Conversion Table*. In this empirical application five Severity Classes are defined with the following upper and lower boundaries,

Table 7.5
Severity Class-Impact Intensity Conversion Table

Severity Class j	Range	Intensity of Social Impact
j=5	$0.000< SC(5) \leq 0.055$	social crisis
j=4	$0.055< SC(4) \leq 0.109$	very severe
j=3	$0.109< SC(3) \leq 0.219$	severe
j=2	$0.219< SC(2) \leq 0.438$	moderate
j=1	$0.438< SC(1) \leq 0.875$	problematic
j=0	$0.875< SC(0) < 1.750$	nuisance

For the seventeen fishing villages in the sample, blocked access to the beach is a *very severe* social problem; well water salinity is a *severe* problem; agricultural land salinity and un/underemployment are problems with a *moderate* severity; poor health is *problematic* and difficulties in fodder & fuelwood collection are the least severe problem or simply an overall *nuisance*. No *social crisis* was identified using our method of indexing social impacts.

Overall, the distribution of Social Impact Indices for farming villages is skewed towards less severe impacts than fishing villages. The problems of fodder & fuelwood collection and agricultural land salinity arising from the advent of shrimp farming are *moderately severe* for farming villages. Blocked access to the brackishwater source (either creek or beach) and well water salinity are *problematic.* Un/under-employment is a *nuisance* whereas, Poor Health is at most a *nuisance* to farming communities.

The aggregate social impact index is a weighted average of social impact indices scaled by the number of villages in a particular category *k*, reporting that a particular impact is disruptive to their general well-being. For our sample of twenty-six villages, agricultural land salinity, blocked access and well water salinity are of *moderate* severity. Un/under-employment and problems in collecting fodder & fuelwood are *problematic.* Health problems are generally a *nuisance* overall, and considered the least severe problem faced by the entire village sample.

7.5.3 Ranking Social Impacts by Severity

Each impact is ranked by the numerical value of the SII for fishing villages and farming villages. These results are presented in the first two columns of Table 7.6. The rank order for the severity of impacts for the entire Kandaleru village sample is presented in the final column of the table below. The exact method used to construct rank orders for these impacts is discussed in Appendix 7F.

Table 7.6
Impacts Ranked by SII

Ranked Impacts	Fishing Villages Rank	Farming Villages Rank	All Villages Aggregate Rank
Well water salinity	2	4	3
Blocked access	1	3	2
Agricultural land salinity	3	2	1
Un/under-employment	4	5	4
Poor health	5	6	6
Fodder & fuelwood	6	1	5

note: a rank of "1" suggests that the associated impact is the most severe impact facing that category of villages.

7.6 How Useful Is the Social Impact Index?

We conclude this chapter with a brief discussion of the Social Impact Index as a useful measure of impact severity, and for ranking purposes. Knowledge of each impact's severity and its rank order based on the social impact index is useful to policy makers. First, separation of villages into categories based on common characteristics enable policy makers to devise targeted strategies for each group. By assessing the aggregate severity index for each impact, policy makers are able to formulate an overall strategy to alleviate the most severe social impacts facing the entire Kandaleru region. By focusing on the index value of impacts of a specific category (i.e. occupation or location) policy makers can target the most severe impacts facing a particular group of villages.

This research suggests that it is not enough to only discover the extent to which villages suffer in some capacity to different social impacts (see Table 7.0). Moreover, the mean rank score provides important information beyond that of assessing whether an impact is a problem facing a village or not (see Table 7.2). It is one way of generally assessing the relative importance of each social impact. The Social Impact Index provides a numerical and qualitative measure for *severity* of a social impact on the well-being of a village community. It differs from simply taking the mean of the village ranks as it gives more weight to the impacts that a greater number of villages declared to be problematic. Secondly, it provides a method to assess social impacts of villages grouped by common characteristic such as location or occupation. As each impact is assigned a severity index, the impact shown to be most severely disrupting the livelihood of inhabitants can be addressed with urgency.

Appendix 7A

Assessing Responses of Individuals in A Given Village

7A.0 Constructing An Aggregate Village Response & Measure of Frequency

This section presents the methodology used to construct an aggregate village response to the question of whether a particular social impact *i* is disruptive to a given village *n*. The aggregate response, $A_i^{n,k}$ is defined by the following rules,

$$(1A) \qquad If \frac{\sum_1^p a_i^{n,p}}{P^n} > T_i \Rightarrow A_i^{n,k} = 1$$

This suggests that in aggregate, village *n* does find a given impact *i* more likely to be problematic. The alternative,

$$(1B) \qquad If \frac{\sum_1^p a_i^{n,p}}{P^n} \leq T_i \Rightarrow A_i^{n,k} = 0$$

suggests that in aggregate, village *n* does not find impact *i* problematic. In the above expressions, the response to the first question by each individual of the sample population in a given village *n* is denoted as $a_i^{n,p}$. The sample population of village *n* is denoted as P^n. Each *p* respondent in village *n,* is one individual living in a village with population *P* and $p \in (1,2,..P)$. *K* is the number of categories with which the sample villages can be separated (see Section 7.4.1).

The expressions in (1A) and (1B) are essentially the proportion of the sample population (in percentage terms) that claim that the impact in question is a problem faced by their family. This expression therefore takes a value between 1 and 100. T_i is the thresh-hold assigned to denote whether the aggregate village response suggests that impact *i* is problematic for village *n* of category *k.* In this analysis, the thresh-hold value assigned is T_i = 50. This value is assigned for both creek-based villages for which individual response data is available and sea-based villages for which the dis-aggregated data is not available. As mentioned earlier, individual data collected from sea-based villages are held by the Central Institute for Brackishwater Aquaculture and unavailable for further inspection due to the collaborative agreements made between myself and CIBA.

Each cell of Table 7.0 is therefore filled by the result of the following calculation, namely,

$$\text{(1C)} \qquad Aggregate\ Frequency = \frac{\sum_{1}^{N} A_i^{n,k}}{N^k}$$

where N^k is the number of villages in the sample and where all other variables are as previously defined.

While it is clear that the value assigned to the thresh-hold has a direct impact on the aggregate frequency of a particular impact (Table 7.0 would be slightly changed given a different thresh-hold), based on simulation experiments, the relative rank of the impact frequencies remain the same when the thresh-hold level is raised to 60 and 70 or lowered to 40. The present level of $T_i = 50$ seems reasonable in this initial investigation of social impacts.

7A.1 Defining A Particular Village Impact's Rank Order

The rank order assigned to each impact for each sample village depends on the proportion of the sample population that claim an impact to be most disruptive to their overall village welfare according to the *ranking game.* The ranking game asks each individual *a* in village *n* to rank each social impact by his/her perception of its disruption to their overall welfare. The game is played in six rounds. As discussed in Chapter 2, section 2.4.4. of this dissertation,

> ...the assembled household heads were asked to *rank* in order of importance each impact drawn from the discussion and the questionnaire. This was accomplished by asking each individual in the assembled group to indicate which impact was - most important to them by raising their hand when it was announced. For example, we asked "please raise your hand if you think well water salinity is the most important problem you face from the six major problems discussed." Next, we inserted "agricultural land salinity/loss of agricultural crops" for "well water salinity" and repeated the question. We did the same for all six impacts. Next, we asked individuals to raise their hands when the second most important impact to their general well-being was called out. Again the above mentioned question

> was repeated for each impact. We used this line of questioning in *six rounds* until all six impacts were ranked.

The results of the ranking game for Gummaladabba village are presented in Table 7A.1 below. It is clear from the results that the rows do not necessarily add up to 100 percent. The last column in the table indicates the amount (in percentage terms) that the row sum deviates from 100 percent. In Rounds One, Two, Three, Four, and Six the rows sum to greater than 100 percent. This suggests that some individuals voted more than once. In Round Five, the row values sum to less than 100 percent. This suggests that some individuals did not cast a vote throughout this round of the game.

Because each individual's response was not followed throughout the game (we counted hands as discussed in Chapter 2) it is impossible to tell who voted multiple times and who didn't vote at all. This is one clear limitation of the ranking game adopted in the village survey. Nonetheless, from the percentage scores in each cell it is possible to rank each impact according to how problematic the sample population viewed each impact relative to each of the others.

For example, using the results of the ranking game, a village aggregate rank can be constructed for Gummaladabba village. The highest rank is given to the impact with the most number of votes according to Round One. Therefore, using these data, *blocked access* is awarded a rank of "1", suggesting it is the most problematic of all the impacts. The second highest rank is awarded to the impact with the highest number of votes in Round Two. Thus, *well water salinity* is awarded a village rank of "2". Using this method for the remaining rounds, *poor health* is awarded a rank of "3", *agricultural land salinity* is awarded a rank of "4", *unemployment* is awarded a rank of "5" and *fodder and fuelwood collocation problems* is awarded a rank of "6". A similar table to that of Table 7A.1 can be constructed for each of the remaining villages in the sample.

Table 7A.1
Results of the Ranking Game for Gummaladabba Village

%	*WWSALIN*	*ACCESS*	*AGSALIN*	*UNEMPL*	*HEALTH*	*FODFUEL*	+/-
Round One	18	**82** rank (1)	0	0	8	0	+8
Round Two	**72** rank (2)	14	15	0	14	0	+15
Round Three	4	2	35	0	**66** rank (3)	0	+7
Round Four	0	1	**63** rank (4)	35	3	2	+4
Round Five	0	0	23	**53** rank (5)	4	8	-12
Round Six	0	0	14	33	5	**55** rank (6)	+7

source of data: Patil & Village Survey, 1997; note: **bold number** represents winner of each round; number in parenthesis is the aggregate village rank awarded for each impact; percentages rounded to the nearest whole number. The percentage value in each cell is calculated as the number of votes received divided by the sample population. The sample population surveyed in Gummaladabba village was 137 individuals.

Formally stated, if impact j is found to be the most problematic of all M impacts for village n, then

(1D) $$r_j^n = 1$$

The aggregate village rank of impact j for the village is therefore assigned a rank value of "1". The impact with the highest frequency in Round Two is given a rank of "2". The remaining M impacts are ranked in this way. The value assigned to r_j^n is used to construct the Social Impact Index (see Section 7.4.1).

7A.1 Defining the Mean Rank Score for Villages Belonging to Category k

The average rank score assigned to impact i for villages belonging to category k is defined as,

(1E) $$\frac{\sum r_i^{n,k}}{N^k}$$

where all variables are as previously defined.

Appendix 7B

Summary of Individual Respondents of Creek-Based Village Survey

Table 7B.1
Summary Statistics of Surveyed Creek-Based Villages

VILLAGE NAME	OCCUP*	POP**	HH**	AVG. SIZE	% POP SURVEYED***
Gummaladabba	fishing	1123	250	4.49	12.2
Lingavaram	farming	100	23	4.34	41.0
Venkatreddypalem	farming	88	20	4.40	60.2
Momidi	farming	120	32	3.75	31.6
Tikkavaram	farming	240	68	3.52	40.0
Krishnapattanam	fishing	510	95	5.36	9.4
Bestapalem	farming	1265	284	4.45	8.3
Puddiparti	farming	240	54	4.44	36.3
Thirumalampalem	farming	600	273	2.19	17.0
Tippaguntapalem	farming	64	24	2.66	65.6

source: *denotes data from Patil & KAA Database, 1997; **denotes data from BFDA, 1996; ***denotes data from Patil & Village Survey, 1997.

Table 7B.2
% of sample population that indicated social impact is problematic

CREEK-BASED VILLAGES	WWSALIN	ACCESS	AGSALIN	UNEMPL	HEALTH	FODFUL
Gummaladabba	73	92	62	86	45	59
Lingavaram	64	62	68	32	12	87
Venkatreddypalem	72	77	75	26	9	94
Momidi	54	23	28	21	0	66
Tikkavaram	23	34	14	34	0	78
Krishnapattanam	45	66	58	41	48	56
Bestapalem	87	19	72	37	17	81
Puddiparti	94	71	51	24	26	55
Thirumalampalem	82	24	89	31	12	69
Tippaguntapalem	19	10	9	19	0	66

source of data: Patil & Village Survey, 1997; note: the value in each cell determines the value taken by $A_i^{n,k}$ as discussed in Appendix 7A.

Appendix 7C

Summary of Ranked Mean Score

Table 7C.1

Summary of Ranked Impact Data by Village Location

Impact	Rank	Mean	S.D.	Minimum	Maximum
16 Sea-Based Villages					
WWSALIN	2	2.56	1.36	1	5
ACCESS	1	1.63	0.88	1	4
AGSALIN	3	3.00	1.09	1	5
UNEMPL	4	3.43	1.21	1	5
HEALTH	5	4.43	0.81	3	5
FODFUEL	6	6.00	0.00	6	6
10 Creek-Based Villages					
WWSALIN	2	2.50	0.97	1	4
ACCESS	3	2.51	1.26	1	4
AGSALIN	4	2.70	1.33	1	5
UNEMPL	5	4.90	0.31	4	5
HEALTH	6	6.00	0.00	6	6
FODFUEL	1	2.10	1.19	1	4
26 Village Sample					
WWSALIN	2	2.54	1.21	1	5
ACCESS	1	1.96	1.11	1	4
AGSALIN	3	2.88	1.17	1	5
UNEMPL	4	4.00	1.20	1	5
HEALTH	6	5.03	0.99	3	6
FODFUEL	5	4.50	2.06	1	6

source of data: Patil & Village Survey, 1997

Appendix 7D
Some Assumptions & Caveats

There are two elementary aspects of most indicators: (i) a conceptual aspect which defines what is exactly being measured, and (ii) a data aspect which can limit the strength of the indicator by the lack of availability and/or lack of quality of relevant statistics. Moreover, McGranham et al (1985:5) suggest that most indicators are not necessarily direct and full measures of what they are intended to indicate but often indirect or incomplete measures. To minimise this problem, we define social impact index as an impact of severity, given several assumptions and caveats briefly discussed in this appendix.

The SII has some additional meaning not offered by simply comparing the frequency or the mean score of aggregate village responses. This is because the index employs both data which captures frequency and rank data in its construction. However, there are several caveats and assumptions made to make our measure of impact severity a functional index, given the nature and quality of the data.

7D.0 Perceptions differ among villagers and between villages

It is not possible to conclude that the severity of an impact is perceived as the same in two villages where an impact *i* is ranked as "M", for example. This is a well known problem discussed in the literature, but not necessarily problematic to ordering ranks (Gibbons et al, 1977: 4-12). Several studies have shown that despite the fact that each individual in a given population has a different set of tastes and preferences, it is possible to rank the order of preferences in a meaningful way (see Marden, 1995: 97-112 for a review of some well known studies).

7D.1 Loss of information due to aggregation

In constructing the Social Impact Index, some important information may be lost due to aggregation. For example, due to the nature of the survey instrument, data collected from each member of the village population is aggregated to form a village rank of each impact. This rank is based on the relative frequency of an even being problematic. There may also be some loss of information due to the nature in which aggregation takes place. For example, their could be the case that one village (in aggregate) may suffer heavily from one or all six impacts (that is, the percentage of respondents answering "yes" to the question, *Do you or your family face impact i?* is high—80 percent or above). The second village may suffer only mildly (that is, the percentage of respondents answering "yes" to the question, *Do you or your family face impact i?* is lower—50 percent, for example. Nonetheless, the SII captures both villages' aggregate response as $A_M^{n,k}=1$ in the Social Impact Index.

7D.3 Ranks preferred to frequency

There is no question that the frequency data generated from the responses of the *ranking game* (see Appendix 7A, section 7A.1) is not ideal as a result of irregularities. Nonetheless, constructing aggregate ranks while losing some information, does order each impact in a uniform way across all villages in the sample. In this respect, using ranks as opposed to the frequency in building the model seems appropriate.

While the percent values presented in Table 7B.1 could serve as a severity index in itself, the unavailability of similar data on sea-based villages (at present) make the aggregated rank order more useful for comparisons across the 26 surveyed villages. As an aside, the denominator in (1) or (2) takes into account the possible situation where both villages' aggregate rank of an impact *i* is "M", but one of the villages actually suffers from the impact while the other does not.

7D.2 Homogeneity based on socio-economics or demography

Following Diaconis (1988, 1989), creating K groups based on socio-economic or demographic lines addresses some of the criticisms concerning ordering data elicited from populations with no known common or hypothesised perceptions. The assumption that sea-based fishing villages face similar problems to each other than they do to farming villages seems reasonable. Similarly, farming villages, are more likely to face similar problems to other farming villages. Moreover, this was found to be true of the 26 village sample (see Table 7.0). This result suggests a homogeneity between villages of a particular occupation or location. In the case of our sample, occupation usually defines village location, and vice-versa. In this respect, their may be some value to assessing severity based on groups of villages clustered by some common characteristic, rather than individually. This seems particularly true for policy recommendations (Gibbons et al, 1977:273-280).

7D.4 All villages are given equal weight

The Social Impact Index in (1) is constructed on the assumption that each village in the sample is given equal weight. This means that the concerns of a village such as Gummaladabba with a population of 1,123 inhabitants is weighted equally to the concerns of a village such as the less populated Tippaguntapalem (64 inhabitants). In assessing the social impacts of the Kandaleru region, we therefore assume that there are an equal number of fishing villages as farming villages.

Appendix 7E

Comparing Ranks Based on Frequency, Mean Rank Score and Simulation Experiments on θ

In this section some results of simulation experiments on *theta* are presented. Next, we compare the ranks based on the relative frequency of occurrence of a social impact, the mean score of the ranking game and the numerical value of the social impact index (for selected values of theta) and for each impact. This, in part, justifies the use of the Social Impact Index over general statistical methods of organising and comparing data.

7E.0 Choosing a Value for Theta

It is clear that the value of *theta* changes the numerical value of the SII as defined in (1). The question remains, what value of *theta* is sensible to use in assessing impact severity? We suggest that by assigning *theta = 2,* the necessary criteria to ensure that an impact that *(i)* faces a greater number of villages, and (ii) is ranked higher relative to the others (i.e. the highest rank is "1"). Table 7E.1 presents the numerical values of the SII for different theta values.

Table 7E.1
Simulations on Theta (Fishing Villages Only)

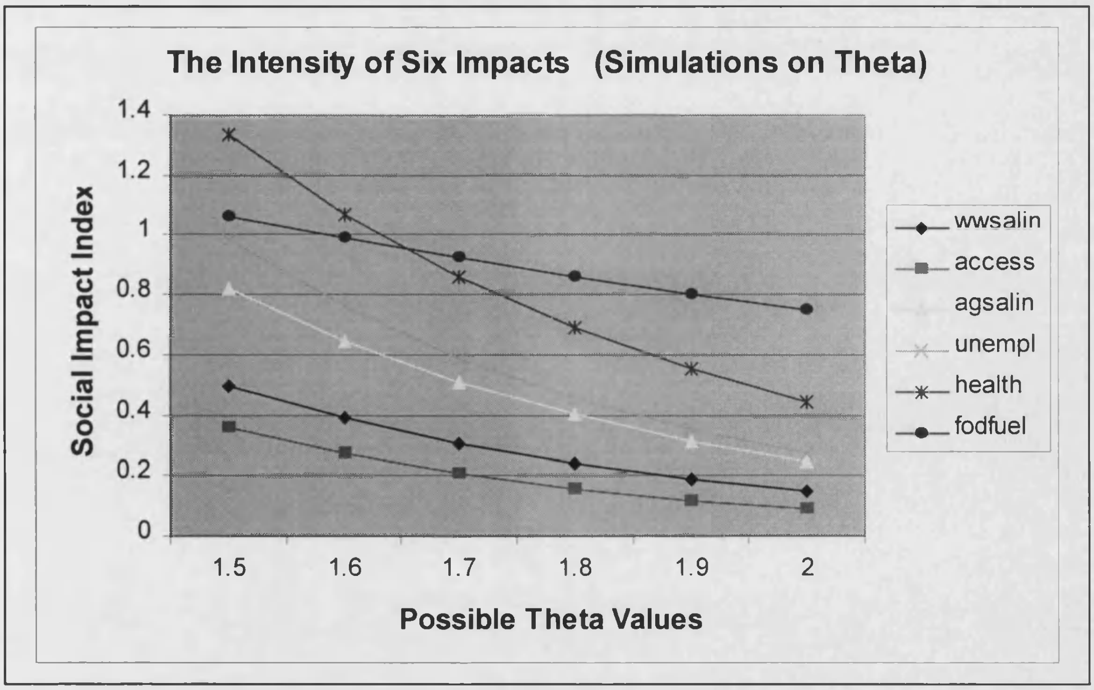
SII	WWSALIN	ACCESS	AGSALIN	UNEMPL	HEALTH	FODFUL
Theta=0.0	18.000	23.000	30.000	46.000	36.000	3.000
Theta=0.5	5.427	5.750	9.045	12.758	12.000	2.121
Theta=0.6	4.270	4.358	7.117	9.872	9.633	1.979
Theta=0.7	3.360	3.303	5.599	7.638	7.733	1.847
Theta=0.8	2.643	2.503	4.406	5.910	6.207	1.723
Theta=0.9	2.080	1.897	3.466	4.573	4.983	1.608
Theta=1.0	1.636	1.438	2.727	3.538	4.000	1.500
Theta=1.1	1.287	1.089	2.146	2.738	3.211	1.400
Theta=1.2	1.013	0.826	1.688	2.118	2.578	1.306
Theta=1.3	0.797	0.626	1.328	1.639	2.069	1.218
Theta=1.4	0.627	0.474	1.045	1.268	1.661	1.137
Theta=1.5	0.493	0.359	0.822	0.981	1.333	1.061
Theta=1.6	0.388	0.272	0.647	0.759	1.070	0.990
Theta=1.7	0.305	0.206	0.509	0.588	0.859	0.923
Theta=1.8	0.240	0.156	0.401	0.455	0.690	0.862
Theta=1.9	0.189	0.119	0.315	0.352	0.554	0.804
Theta=2.0	0.149	0.090	0.248	0.272	0.444	0.750

note: data is for the 17 fishing village sample only

As discussed in Section 7.4.5, the Social Impact Index is smaller for higher values of *theta*. Moreover, the numerical value of the SII is smaller (i.e. that is, the impact is more severe) for a given impact if a greater number of villages report that particular impact as more problematic relative to the others through the ranking game (i.e. the frequency is higher). The value assigned to *theta* determines the importance assigned to the frequency of reporting a given impact as problematic. Figure 7E.1 illustrates that the value of *theta* is important in both determining the numerical value of the SII which we qualify as an index of severity and for ranking purposes.

Simulation experiments on the SII for different values of *theta* reveal that each social impact maintains its rank order for values of *theta* greater than 1.65. This means that the rank order does not "switch" for a marginal increase in *theta.* Similar simulation experiments conducted on the farming village sample reveal that the "switching" value of theta after which impacts maintain their rank is 1.60. The "switching" value of theta for the total village sample is 1.65.

Figure 7E.1
Identifying the "Switching" Value of Theta



note: The above figure represents the scaling parameter for fishing villages only.

7E.1 Comparing Ranks

Overall, the rank order of impacts as delineated by the social impact index (with $\theta=2$) is equivalent to the ranks based on the arithmetic mean of the sample but clearly favoured over the relative frequency (see Table 7E.2).

The ranks given by the mean score and the SII (Theta =2) are the same. A similar relationship holds for farming villages. That is to say, that the ranking determined by adjusting *theta* square with the information provided by the frequency and the mean score value for values of *theta* higher than 1.7 (see Figure 7E.1). The theta value chosen to assess impact severity is therefore, two.[20]

Table 7E.2
Selected Methods to Rank Impacts

	WWSALIN	ACCESS	AGSALIN	UNEMPL	HEALTH	FODFUL
frequency	0.647 (3 or 4)	0.941 (1)	0.647 (3 or 4)	0.765 (2)	0.529 (5)	0.118 (6)
mean score	2.412 (2)	1.588 (1)	3.118 (3)	3.706 (4)	4.588 (5)	5.647 (6)
ratio of rank sum to number of vill reporting a problem with Theta=0	3.727 (2)	1.688 (1)	4.818 (3)	4.846 (4)	8.667 (5)	48.000 (6)
SII, Theta=0	18.000 (2)	23.000 (3)	30.000 (4)	46.000 (6)	36.000 (5)	3.000 (1)
SII,Theta=0.5	5.427 (2)	5.750 (3)	9.045 (4)	12.758 (6)	12.000 (5)	2.121 (1)
SII, Theta=1.0	1.636 (3)	1.438 (1)	2.727 (4)	3.538 (5)	4.000 (6)	1.500 (2)
SII, Theta=1.5	0.493 (2)	0.359 (1)	0.822 (3)	0.981 (4)	1.333 (6)	1.061 (5)
SII. Theta=2.0	0.149 (2)	0.090 (1)	0.248 (3)	0.272 (4)	0.444 (5)	0.750 (6)

note: ranks in parenthesis; these figures pertain to fishing villages only

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[20] The severity index was calculated and compared using values of theta greater than the thresh-hold value and up to two. In each case, the degree of severity as assessed by the severity impact conversion table for each impact remains the same. Even fodfuel and health remain in the same category, despite the divergence in their severity index value after the thresh-hold value of 1.65.

Appendix 7F

Ranking Social Impacts

Identifying both the severity of a problem and its rank relative to other problems can give policy makers an indication of which impacts require immediate attention. Given the data collected from the village survey, a method is employed to rank social impacts by *severity.*

7F.0 Ranking Impacts for A Particular Village

The rank order of a given social impact *i* is determined relative to the assigned rank of the other *M-1* social impacts under investigation. For a specific village *n,* the rank order of any impact *i* is determined through the method presented in Appendix 7A.1.

7F.1 Ranking Impacts for Villages with A Common Trait, k

The rank order of a given social impact *i* for a group of villages categorised by a common characteristic *k,* is determined relative to the assigned rank of the other *M-1* social impacts under investigation for the group. For a group of *n* villages, the rank order of social impact *z* is determined through the following rules,

$$(1F) \qquad R_i^n = A_i^n r_i^n \qquad n=1,2,3,\ldots,N;\ \textit{for all } i = 1,2,\ldots M$$

where A_i^n takes a binary value as discussed earlier according to Appendix 7A.0 and the numerical rank value of r_i^n is as determined in Appendix 7A.1. R_i^n can take any value between 0 and S. It can take the value 0 only if $A_i^n = 0$. Social Impact *z,* SII_z^k is given a ranking of "1", if and only if,

$$(1G)\qquad \frac{\sum_{1}^{N} R_z^{n,k}}{(\sum_{1}^{N} A_z^{n,k})^{\theta}} < \frac{\sum_{1}^{N} R_i^{n,k}}{(\sum_{1}^{N} A_i^{n,k})^{\theta}} \quad \textbf{for all } i \neq z$$

$$i=1,2,3,\ldots z,\ldots M;\ n=1,2,3,\ldots,N;\ k \in (1,2,\ldots K) \text{ and } 1 \leq k \leq K$$

where $\sum_{1}^{N} R_z^{n,k} = \sum_{1}^{N} A_z^{n,k} r_z^{n,k}$ is the sum of the rank orders of problematic impact z for all n villages categorised by k. The denominator of (1G) is comprised of (i) a weight, $\sum_{1}^{n} A_z^{n,k}$ which counts the number of villages in each category k that responds such that $A_z^{n,k} = 1$; and (ii) an exponent θ which deflates $\sum_{1}^{N} R_z^{n,k}$ based on the number of villages reporting impact z as disruptive to their general well-being.[21] All other variables and parameters are as previously defined.

7F.2 Ranking Impacts for the Aggregated Sample

Finally, we wish to rank the aggregate Social Impact Index, SII_i for all N villages across all K categories of our sample. Similar to the case described above for a category of villages, the rank order of a given social impact z for all villages in our sample is determined relative to the assigned rank of the other *M-1* social impacts. For all N villages, the rank order of social impact z is determined through the following adaptation of (2). Impact z is given a ranking of #1, if and only if,

$$(1H)\qquad \frac{1}{K}\sum_{1}^{K} \frac{\sum_{1}^{N} R_z^{n,k}}{(\sum_{1}^{N} A_z^{n,k})^{\theta}} < \frac{1}{K}\sum_{1}^{K} \frac{\sum_{1}^{N} R_i^{n,k}}{(\sum_{1}^{N} A_i^{n,k})^{\theta}} \quad \textbf{for all } i \neq z$$

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[21] In our empirical estimation of (6) we define $\theta = 2$.

where z is one of M social impacts under investigation and all variables and parameters are as previously defined.[22]

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[22] The left hand side of (7) is simply the numerical value of the Social Impact Index of impact *i*, $\mathrm{SII}_z = \frac{1}{K}\sum SII_z^k$.

Chapter 8
Identifying the Determinants of Shrimp Farming's Negative Social Impacts on South-eastern Indian Coastal and Inland Villages

8.0 Introduction

The transformation occurring in the coastal regions of India as a result of shrimp farming has affected the lives of its inhabitants. However, its effects have been poorly documented. Nonetheless, during the past ten years, the shrimp farming sector has developed an increasingly bad reputation among those concerned with the well-being of rural peoples. This is partially a result of flagrant violations of the law by shrimp farmers (SC Notification, 1996). It is also partially a result of leaving the sector to operate in absence of clear laws governing operating practices. In absence of clear guidelines, there have been increasing conflicts between those operating shrimp farms and those inhabiting villages adjacent to them.

These conflicts have arisen as a result of the various stresses placed on the environment and the way in which these stresses have directly or indirectly affected the well-being of local inhabitants. For example, shrimp production has been blamed for ground water abstraction (NACA, 1994:46); the loss of animal grazing and fodder collection areas due to land conversion (NEERI, 1996); agricultural land and village well water salinity (Flaherty & Karnjanakesorn, 1995); the rise in health problems inflicting fisher-folk (PREPARE, 1996); and blocked access to major waterways as a result of barbed wire fences and guards (Maybin et al, 1997).[1]

This chapter assesses the impacts of the shrimp farming sector on inhabitants of the Kandaleru region. Specifically, three questions are explored employing probit and ordered probit analysis:

(i) What are the determinants of the social impacts faced by coastal and inland communities as a result of shrimp farming?

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[1] See Chapter One for a detailed description of these externalities.

(ii) What farm and village characteristics, if any, explain why some villages are more or less likely to suffer from the negative consequences of a given social impact?

(iii) What impact does a small change in a significant village or farm characteristic have on the probability that the region (the villages in the sample) suffers from a particular socio-economic or environmental problem?

This empirical investigation is presented in four sections. Section 8.1 presents a brief review of some relevant literature. Section 8.2 presents an overview of the methodology used in this assessment and a description of the data. Section 8.3 formally presents two established statistical techniques, probit and ordered probit models used to analyse village responses. Section 8.4 presents the explanatory variables and a statistical summary. Finally, section 8.5 presents the estimation results and offers some policy prescriptions and general conclusions.

8.1 A Review of the Literature

The use of probit and ordered probit models in analysing "rank" data from household surveys is prolific in the literature as a result of the ease with which qualitative data can be examined. These studies are often interdisciplinary in nature and span the psychological, sociological and economic literature.[2] Specifically, a growing literature exists on the economics of well-being. Within this field, the determinants of happiness are often explored (Oswald, 1997). In these studies, ordered or ranked classifications of well-being, happiness, or satisfaction are used to approximate neo-classical "utility".

A second prolific application of probit and ordered probit models has been in the field of labour economics. Oswald and Clark (1996), for example examine whether employee job satisfaction follows a U-shaped behaviour with respect to age. Blanchflower and Oswald (1997) examine the effect of unemployment on the happiness of youth in Eastern Europe. More specific to Indian rural employment behaviour, Simmons and Salinder (1995) examine the degree to which the pattern of non-farm employment has changed in the Punjabi

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[2] see Marden (1995) for a review of such studies.

countryside. Specifically, they examine the determinants of decisions made by rural households to participate in non-farm activity using probit models.

It is less evident how both probit and ordered probit models are constructed to assess socio-economic and environmental impacts on rural inhabitants. Nonetheless, it is a straightforward extension of its more traditional applications: The left-hand side variable is a vector of ordered rankings and the right-hand side variables (usually characteristics of the population in question) are used to explain them. This study, therefore is similar in spirit to the previous body of work employing probit and ordered probit models. However, it crudely analyses the relative degree to which negative externalities are reducing the welfare of village communities located adjacent to shrimp farming clusters.

At present, the literature is devoid of any village impact assessment studies with respect to brackishwater shrimp aquaculture. It is unclear whether characteristics of shrimp farms (i.e. their size, for example), socio-economic or demographic characteristics of villages (i.e. their wealth or average household size, for example) or a combination of both help to explain why certain impacts are relatively more problematic within a particular village, and why certain impacts are more severe for the entire region. Employing probit and ordered probit analysis identifies key factors that adequately explain village survey responses. Given the nature of the data, Probit and Ordered Probit models facilitate this kind of investigation.

8.2 Constructing the Data Set: A Review

The objective of this analysis is to identify the determinants of the social impacts faced by rural inhabitants of the Kandaleru region as a result of shrimp farming. Three types of data are required, namely, shrimp farm cluster characteristics; socio-economic and demographic data on sample villages; and data identifying the existence of and relative severity of social impacts facing sample villages. From these data, it is possible to determine which specific farm and village characteristics explain the responses elicited via the village survey.

8.2.1 Shrimp Cluster & Village Characteristics

Both primary and secondary data were collected to construct profiles for each of the twenty-six shrimp clusters and their adjacent villages. Shrimp farm cluster characteristics for creek-based farms were collected by primary survey from over 500 shrimp farms operating along the Kandaleru creek. Equivalent data on sea-based farm characteristics were made available from the BFDA. Socio-economic and demographic data collected from each village were collected via formal survey and the BFDA.[3]

8.2.2 Social Impacts

Six major social impacts adversely affect the well-being of the Kandaleru region's inhabitants. They include well water salinity, agricultural land salinity, blocked access to the Kandaleru creek or Bay of Bengal, the conversion of traditional areas originally used for fodder and fuelwood collection to shrimp farms, unemployment and poor health. Each impact was identified using community survey and rapid rural appraisal techniques. First, respondents were asked for a definitive "Yes" or "No" answer to the following question: *Has aquaculture development led to your village suffering from (say, impact A)?* Second, respondents were asked to rank the relative severity of each social impact on their overall well-being.[4]

Thus, two distinct pieces of information were obtained. First, the availability of a "Yes/No" response enables the construction of a binary (one/zero) dependent variable used as the dependent variable in the probit model. It reveals whether a particular social impact is problematic in a given village. Second, the aggregate village ranking of social impacts enables construction of an ordinal variable that serves as the dependent variable in the ordered probit model. It provides a way in which to compare how villages perceive each social

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[3] See Chapter 2 for a detailed description of the data.

[4] An aggregate village relative ranking of each of impact is constructed from individual responses according to the method described in an earlier chapter.

impact relative to the others. Moreover, both pieces of information are necessary for completeness.

Data used to construct the binary dependent variable in the probit model and the ranked data used in the ordered probit model are subject to distortions or "noise". One type of distortion that affects the rank order of a given impact as defined by the ranking game discussed in Chapter 7, Appendix 7A, Section 7A.1. A second distortion is important to the binary value assigned to the left-hand side variable of the Probit model. This distortion is a result of compensation schemes introduced by the government that force shrimp farmers to pay villages for environmental and social damages. This introduces a bias in the response of the first question asked relative to the answer provided by the rank. For example, the first question requires a definitive, "yes" or "no" answer to whether the village is facing a given problem, say well water salinity. It is entirely possible that each and every well in a given village is saline and therefore abandoned. Consequently, when asked whether the village has polluted wells, the answer is a clear "yes". However, because this particular village is receiving drinking water trucked in daily at the expense of some adjacent corporate shrimp farm, the village ranks well water salinity as the least important problem facing the village, relative to the other five impacts. The effect of compensation schemes are most likely embedded in responses to the ranking game. It is therefore necessary to use both pieces of data in the attempt to identify the determinants of social impacts and to identify reasons behind their relative severity.

8.2.3 Caveats, Assumptions and Objectives

The method of ranking, measuring and explaining subjective measures of severity is taken with a degree of caution in the economic literature. However, the frequency of using this approach is growing (Oswald, 1997). Several areas of concern, or caveats raised by economists are briefly addressed in the context of this analysis. First, the subjective rank given for each impact by a village population is not equivalent to assigning a level of severity to that impact. Second, perceptions among differ people within a village and between villages are undoubtedly different from one another. The question remains, how different? Finally, each individual's perception of the actual intensity of a given negative impact is likely to vary. However, are they similar enough to warrant aggregation? Despite these obvious philosophical musings and in absence of rigorous environmental and socio-economic data, it is still possible to unveil findings of an unexplored, but highly exposed area of investigation.[5]

This study merely uses one method to assess the impacts of shrimp farming on rural producers. Given the data, the method employed in this study is complementary to more traditional impact assessments. Moreover, this method enables quantifying and analysing subjective notions of well being, given that data necessary for concrete environmental impact assessments are unavailable. Even more difficult, however is assessing social impacts. Nonetheless, there is growing evidence that subjective data serve as strong predictors of observed behaviour (Clark and Oswald, 1996).

The contribution of this study to the empirical literature is three-fold. First, it provides a first attempt at identifying the existence of impacts faced by coastal communities as a result of shrimp farming. Second, it assesses the determinants of shrimp farming's alleged social impacts. Finally, it offers some explanation as to the magnitude of each impact on sample villages.

8.3 Probit & Ordered Probit Models

8.3.1 The Probit Model

The probit model uses maximum likelihood techniques to estimate models with binary dependent variables. In this analysis, the probit model is specified as

$$(1) \qquad \Pr(A_i^{n,k} \neq 0) = F(x\beta)$$

where $A_i^{n,k}$ takes a zero or one value based on the answer given by village n to the following question, *have you or your family suffered from impact i as a result of shrimp farming?* If the aggregated village response reveals that impact i is not

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[5] Other important caveats and assumptions worth noting are discussed in Chapter 7, Appendix

a problem facing village n, then $A_i^{n,k} = 0$. In contrast, if the aggregated village response reveals that impact i is indeed a problem facing village n, then $A_i^{n,k} = 1$.[6] $F(x\beta)$ is the cumulative normal distribution function with a mean of zero and a variance of one. x is a vector of explanatory variables and β is a vector of associated estimated coefficients.

Interpreting the coefficient results of the estimated probit model is often difficult since it requires thinking in the *z-metric.* For example, a strict interpretation of a coefficient of an explanatory variable, say x_1 is that each one unit increase in x_1 leads to increasing the probit index by its estimated coefficient.[7] A transformation of the probit index to a change in the probability evaluated at the mean, provides a more intuitive and meaningful interpretation. Technically, this is accomplished by the following transformation,

$$\text{(2)} \qquad \frac{\partial . F(x,\beta)}{\partial . x}$$

for all i. The coefficient of the transformation in (2) is specifically interpreted as the change in the probability (evaluated at the mean) for an infinitesimal change in x. In value, it is the height of the normal density function at the mean score, corresponding to the probability of a success (i.e. $A_i^{n,k} = 1$), and multiplied by the x_i coefficient. As the value of (2) approaches unity, the greater the impact that x_i has on the aggregate response of villages in the Kandaleru region.

8.3.2 The Ordered Probit Model

Ordered probit models are used to estimate relationships between an *ordinal* dependent variable and a set of independent explanatory variables.[8] For example the aggregate relative village rank of each social impact affecting a given village, $r_i^{n,k}$ takes on an ordinal rank between one (least severe problem)

7D.

[6] Appendix 7A in Chapter 7 describes the method employed to create aggregate village responses.

[7] For further clarification on the interpretation of the probit score, see Greene (1993).

and six (most severe problem).[9] In the Ordered Probit model, the probability of observing a particular outcome corresponds to the probability that the estimated linear function plus a random error term falls within a range of cut off points estimated for the outcome. The probability of observing a particular outcome as determined by the Ordered Probit model can be represented in the following way,

$$(3) \qquad \Pr(r_i^{n,k} = r | x_j) = \Pr\left(\varepsilon_{r-1} < \sum_j \beta_j x_j + u_j \le \varepsilon_r\right)$$

$$= F\left(\varepsilon_r - \sum_j \beta_j x_j\right) - F\left(\varepsilon_{r-1} - \sum_j \beta_j x_j\right)$$

$$r = 1,2,\ldots 6$$

where ε_r are threshold parameters or cut points; the β_j are the coefficients on the explanatory variables, x_j to be estimated; $r_i^{n,k}$ are the rank orders assigned by village n categorised by k to impact i, relative to each of the other social impacts. The error terms u_j are assumed to be normally distributed. In the parameterization used to empirically estimate (3), the constant term appears in the output as the value of the first cut point. This is merely a result of the statistical package used to estimate the Ordered Probit model.[10]

While the coefficients of the ordered probit model indicate whether villages with a larger quantity or value of the explanatory variable are more or less likely to suffer from negative consequences of the given social impact, they say nothing about the explanatory variable's impact on the magnitude of the problem. A transformation of the ordered probit model is needed to assess the magnitude of an impact given a marginal change in an explanatory variable. Following Long (1997), the coefficients of the ordered probit model are

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[8] An ordinal variable is one that is categorical and ordered.

[9] Please note that this ranking representation is the reverse of that used in determining the severity of social impacts in Chapter Seven. For the purpose of consistency with empirical estimations of the Probit and Ordered Probit model, the ranking data were reformulated such that a rank equal to one represents the least severe impact and a rank equal to six, the most severe impact.

[10] Intercooled Stata 5.0 is used to estimate both probit and ordered probit models.

transformed to reflect the probability of falling into each rank category, given a marginal change in the value of an explanatory variable.[11]

8.4 Explanatory Variables & Data Summary

There are several key variables used to assess the determinants of the responses to the village survey. Table 8.0 presents a roster of shrimp farm cluster characteristics and coastal village characteristics used as explanatory variables in this analysis.[12]

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[11] Greene (1996) illustrates the mechanical way in which to transform ordered probit coefficients in this way. Long (1997), however, made this more accessible by writing and distributing the computer program for this transformation.

[12] Several variables identifying shrimp farm cluster characteristics are highly correlated to each other. To avoid the problem of multi-collinearity, several of these variables are dropped in the specification of the full general Probit and Ordered Probit models (see Appendix 8B).

Table 8.0

VARIABLE	A Roster of Explanatory Variables	Mean	S.D.
	SHRIMP FARM CLUSTER CHARACTERISTICS		
CLSTSZ	size of shrimp farming cluster in hectares	268	197
WSA	size of shrimp farming cluster's water spread area in hectares	180	156
CLSTDST	distance in kilometres from shrimp farm cluster to the adjacent village	1.02	0.4
SEADST	distance in kilometres from shrimp farm cluster to the Bay of Bengal	8.0	12.7
TPNDS	the number of ponds in a shrimp cluster	216	178
TOUTPT	total output of shrimp cluster in metric tonnes	152	139
TCORP	total corporate and private limited companies in each shrimp farming cluster	2.8	3.2
TINDIV	total number of non-corporate shrimp farms in each shrimp farming cluster	21	26
TFARM	total number of farms in each shrimp farming cluster	23	26.7
TOWN	total number of farms producing on land owned by operator in each cluster	11.3	18.6
TLEAS	total number of farms producing on leased land in each cluster	2.3	5.9
TTRAN	total number of farms producing on government transferred land in each cluster	9.0	25.2
	COASTAL VILLAGE CHARACTERISTICS		
WEALTH	average household asset wealth in 1000s of Indian Rupees (see Appendix 8C)	39.6	25.9
PUCPROP	the proportion of pucca houses in each village (a proxy for wealth)		
POP	village population	394	372
VILSZ	village size; number of households in village	113	118
HHSZ	average size of household; number of inhabitants per household	3.6	0.83
OCCUP	occupation of village dummy; 0 denotes farming; 1 denotes fishing	0.65	0.48
BASED	location of village dummy; 0 denotes creek-based; 1 denotes sea-based	0.61	0.45
	SOCIAL IMPACTS (Ranked)		
WSALIN	villages reporting well water salinity problems; ranked impact	4.46	1.21
ACCESS	villages reporting blocked access to the beach or creek; ranked impact	5.03	1.11
AGSALIN	villages reporting salinity of agricultural land; ranked impact	4.11	1.17
UNEMPL	villages reporting unemployment or underemployment; ranked impact	3.00	1.20
HEALTH	villages reporting problems with health; ranked impact	1.96	0.99
FODFUEL	villages reporting problems with fodder & fuelwood collection; ranked impact	2.50	2.06
	SOCIAL IMPACTS (Yes/No)		
WSALIN	proportion of villages reporting well water salinity problems	0.65	0.48
ACCESS	proportion of villages reporting blocked access to the beach or creek	0.73	0.45
AGSALIN	proportion of villages reporting salinity of agricultural land	0.73	0.45
UNEMPL	proportion of villages reporting unemployment or underemployment	0.54	0.50
HEALTH	proportion of villages reporting problems with health	0.34	0.49
FODFUEL	proportion of villages reporting problems with fodder & fuelwood collection	0.38	0.50

note: The mean and standard deviation of the Social Impacts (Ranked) are different from those presented in Chapter Seven. The ranks in this table were reversed to coincide with the general set-up of the ordered probit model. Therefore, the most severe impact is now ranked "6" as opposed to "1".

8.5 Estimation Results

Appendix tables 8A.1 to 8A.6 report the results of the estimated models for each of six social impacts: well water salinity, agricultural land salinity, blocked access, fodder & fuelwood collection problems, health related problems and unemployment. First, the general specification of both ordered probit[13] and general probit models are estimated. Next, the a reduced form of each model are estimated. The results reveal which shrimp farm and village characteristics are important in explaining village survey responses.

8.5.1 Well Water Salinity

Sixty-five percent of the total twenty-six village sample claim that they are adversely affected by well water salinity. In each of these villages, water drawn from at least one communal well is either not fit for local inhabitants' consumption and therefore left idle or known to be deteriorating. Semi-structured group interviews with household heads in each village suggest that shrimp farming is the alleged cause. This is a result of water seepage through the pond bottom into the groundwater. Table 8A.1 presents the estimation results which reveal important factors contributing to drinking water salinity problems. Overall, the results suggest that richer and larger villages suffer less, and that cluster distance to the village and its size matter.

The negative and significant coefficient on the wealth variable of the reduced probit model suggests that villages with higher average household wealth suffer less from well water salinity problems. This is not to say that wells in more wealthy villages are not saline, but rather, that this disruption affects them less than those inhabitants in poorer villages. In fact, the transformed wealth coefficient in the reduced probit model suggests that the probability that

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[13] Because of the ordinal nature of the dependent variable, the following interpretation on the estimated coefficient is possible: a *positive* (negative) and significant coefficient of an explanatory variable suggests that villages with a larger quantity or value of that explanatory variable are *more likely* (less likely) to rank a given social impact as more severe relative to other social impacts than villages with smaller quantities of that variable.

villages face well water salinity problems falls by 60 percent for a marginal increase in village wealth.[14]

Larger villages are less likely to be adversely affected by well water salinity than smaller villages. This is evident from the negative and significant coefficient on village size in both general and reduced ordered probit models. This may be because larger villages tend to have several communal wells and are therefore less concerned if only one of the wells becomes saline. In contrast, smaller villages were observed to have only a few wells.[15] Even if one well becomes saline, it is not surprising that the entire village population feels the full impact of the loss of this resource.

The distance between villages and their adjacent shrimp farming clusters is also an important determinant of reported well water salinity problems. The marginal effect of a change in distance in the reduced probit model is -0.523 and significant at ten percent. This suggests that the probability of Kandaleru villages facing well water salinity problems falls by 52.3 percent when located marginally further away from its adjacent shrimp farming cluster. The village distance from its associated shrimp farm cluster is therefore a key factor in explaining the occurrence of well water salinity problems. The corresponding ordered probit model suggests, however, that distance is not significant in explaining the relative rank given by each village. This is not surprising given the fact that some villages are receiving compensation for their loss (see the example provided in section 8.2.2).

Finally, villages located adjacent to shrimp farming clusters with larger water spread areas are less likely to face water salinity problems than villages adjacent to clusters with smaller water spread areas. Intuitively, the opposite result is expected as a result of direct pond water seepage into village wells. However, salinity of well water is known to be a function of the salt concentration of the groundwater (Rao, 1996; Joseph, 1996). As sub-soil groundwater reservoirs are often expansive, it is likely that seepage from several shrimp farming clusters contribute to its salinity.

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[14] Strictly speaking, this result is for an infinitesimal increase in village wealth, evaluated at the mean. Interpretation of each transformed coefficient, *dF/dx* is similarly defined.

Information on the characteristics of the groundwater reservoirs could perhaps provide a more scientific explanation of why villages next to large water spread areas suffer less from well water salinity phenomenon. Unfortunately, these data are unavailable. In contrast to this result, the hypothesise that the opposite relationship holds for agricultural land salinity problems is tested next. That is, villages located closer to farming clusters with larger culture areas are likely to face problems of agricultural land salinity. Moreover, the relative severity of agricultural land salinity is likely to be greater.

8.5.2 Agricultural Land Salinity

Seventy-three percent of the sample villages reported that agricultural land salinity is a problem in their village. Agricultural land salinity most likely arises as a result of two possible factors, (i) direct seepage of pond water through the pond bottom and into adjacent agricultural plots; (ii) breaches in the bunds which quickly drain pond water directly onto agricultural land. Salinity of agricultural land inhibits the growth of agricultural crops which in turn causes a loss of farm income and/or declines in own-consumption. Both farming and fishing communities were found to rely heavily on maintaining small agriculture plots for own consumption.

Households in primarily agriculturally based villages were found to own or lease small patches of agricultural land. These plots were used to maintain small vegetable gardens for own consumption. Moreover, FAO (1991:38) reports that approximately 74 percent of fishing households in Nellore District engage in some form of agricultural based activity. In most cases, respondents in our survey report that their small vegetable plots, like larger farm land, are located on the outskirts of the village. Oftentimes, these plots are located closest to the shrimp farming cluster.[16] Table 8A.2 reports the estimation results for

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[15] Based on personal observation & official CIBA records (see CIBA, 1997).

[16] The small agricultural plots maintained by fishing households are located on government classified "wasteland". The same wasteland is converted by shrimp farmers for shrimp culture. Therefore, a significant proportion of small agricultural plots are located directly adjacent to these ponds. The fact that these plots are located next to ponds were found to explain why agricultural land salinity problems are such a big problem in villages.

village responses on the existence and relative severity of agricultural land salinity problems.

The estimation results suggest that the size of the culture area in water spread hectares and the primary village occupation explain the existence and severity of agricultural land salinity. The significant and positive coefficient of total culture area in the reduced probit model suggests that villages located adjacent to larger water spread clusters face agricultural salinity problems. The marginal effect, however is small at 0.1 percent. Moreover, the significant and positive coefficient on both ordered probit models suggest that villages located adjacent to shrimp farming clusters with large water spread areas are more likely to rank agricultural land salinity as a more severe problem (relative to other impacts) than villages adjacent to clusters with smaller water spread areas. However, the marginal effect is small.[17]

Occupation is also important factor in explaining why villages are more or less likely to suffer from agricultural land salinity. The negative and significant coefficient on the occupation dummy variable of the ordered probit model suggests that coastal fishing villages are less likely to rank agricultural land salinity as a more severe problem than farming based inland villages. This underscores the fact that while both farming and fishing communities rely on private plots to grow crops for own consumption, farming villages naturally place a greater importance on the degradation of this resource. Moreover, this becomes evident from the fact that the average rank given by fishing villages is 3.88 compared to the 4.55 average rank of farming villages.

8.5.3 Blocked Access

For coastal inhabitants that rely on fishing as a primary or secondary source of income, easy access to the creek and sea is vital. With the advent of shrimp farm development, direct water access has been severely restricted because shrimp farms operate on lands located squarely between villages and the

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[17] The probability that a village increases its rank of agricultural land salinity from 5 to 6 increases at a insignificant rate of 0.5 percent for a marginal increase in culture area. See Appendix 8D.

Bay of Bengal or Kandaleru creek. In fact, seventy-three percent of the survey villages report that blocked access to the brackishwater body is a problem faced by their village. Further investigation revealed that it adversely affects their income generating activities and impedes on their overall well-being.

With each kilogram of cultured shrimp reportedly valued between Rs. 95 and Rs. 150 at the farm gate, shrimp farmers are naturally protective of their crop.[18] Concerned with the possibilities of theft and pond contamination as a result of foul-play, larger shrimp farms tend to employ guards to restrict pedestrian access through the farm. Sea-based villages are particularly affected by restricted access to the Bay of Bengal since fishing activity requires daily access to the beach where fishing craft are kept. Fisher-folk complain that blocked access results in longer commutes to their fishing craft and greater difficulty in transporting their morning catch to the local market. Both restrictions impede their ability to maximise their already meagre income. The estimation results of both probit and ordered probit models presented in Table 8A.3 reveal three important findings discussed below.

Not surprisingly, village occupation is found to be a significant indicator in explaining the existence and relative severity of blocked access. The positive and highly significant coefficient in the reduced probit model underscores the fact that fishing villages are adversely affected by blocked access. They are also more likely to rank the negative consequences of blocked access to the water as a more severe problem than primarily agriculturally based villages.

The distance between shrimp farm clusters and villages is also an important determinant of problems arising from blocked access. Ordered probit estimation results reveal that villages located further away from the shrimp farming cluster are more likely to rank blocked access as a more severe problem than villages located closer to the cluster. This is most likely due to the fact that the further the village is located to the sea, the greater number of obstacles necessary to navigate in order to reach it. A transformation of the ordered probit coefficient suggests that the probability of a village ranking blocked access as the

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[18] For comparative purposes, a kilogram of rice is sold locally for approximately Rs.35; Salt and groundnut command a per kilogram sale price of Rs. 5 and Rs. 20 respectively.

most severe negative eternality facing that village increases by 40.2 percent for a marginal increase in distance.

Finally, village size is found to be a significant factor in explaining welfare loss as a result of blocked access. However, transformation of the coefficient in the reduced probit model reveals that given a marginal increase in village population, the probability that the severity of this impact increases only slightly (less than one percent). The magnitude of this variable's impact is therefore very small.

8.5.4 Fodder & Fuelwood Collection

One primary responsibility of village women is to collect fuelwood used for cooking and heating. Nearby shrubs and thorny bushes, the primary sources of fuelwood and one time growing in abundance next to the Kandaleru creek on government and private "wasteland" have been cleared for shrimp farm development. As a result, the abundance of this resource and relative ease of collecting it has significantly declined. Similarly, before the advent of shrimp farming, domestic animals grazed on open access wasteland. As a result of shrimp farm encroachment of this land, nearby grass and fodder for animal consumption has become increasingly more scarce.

Thirty-eight percent of the village sample reported that fodder and fuelwood collection has been a problem as a result of shrimp aquaculture development in the region. However, whereas only twelve percent of fishing villages report this as a problem, an overwhelming majority of the farming villages (eighty-nine percent) report it as a significant disruption to their overall well-being. This is not surprising given the occupational and locational differences between farming and fishing communities. First, farming villages tend to own many animals such as cows and water buffalo, while fishing communities do not. Second, fishing villages are located predominantly near the sea, while farming villages are located near the Kandaleru creek. Whereas shrimp farms obstruct the access of fisher-folk to the sea, they do not tend to obstruct access to areas where these inhabitants collect fuelwood. The opposite seems to hold true for farming villages. Creek-based farms are located between farming village and the creek and therefore occupy land traditionally used for grazing animals and for fuelwood collection.

These facts are underscored by the econometric results presented in Table 8A.4. The estimation of both general and reduced form ordered probit and probit models suggest that inland farming villages engaged in agriculture and located further from the Bay of Bengal are more likely to identify fodder and fuelwood collection as a more severe problem than sea based villages engaged in fishing or farming activities. Village location and occupation therefore drive this result.

Secondly, the size of a shrimp farm cluster is found to be significant. The negative and significant coefficient in the reduced probit model suggests that villages closer to larger shrimp farm clusters face fewer fodder and fuelwood collection problems. It's impact is very small, however. Finally, villages located further from shrimp farms are likely to face less severe problems than those located closer. In fact, the transformed probit coefficient suggests that given a marginal increase in distance, the probability that fodder and fuelwood collection is a problem falls by 24 percent. Moreover, the transformed ordered probit results suggest that the probability of villages falling into the least severe rank category increases by 64 percent for a marginal increase in distance. The estimation results are therefore consistent and logical.

8.5.5 Unemployment

There is considerable agreement in the literature that shrimp farming is displacing traditional employment opportunities for coastal inhabitants. This is particularly alleged for agricultural labour.[19] This research suggests, however, that contrary to popular opinion, it is not farming communities that are facing unemployment or underemployment as a consequence of shrimp farm development, but rather fishing communities. The survey results indicate that seventy-six percent of all fishing communities reported that they have somehow suffered from unemployment or underemployment as a result of shrimp farming

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[19] A review of the relevant literature is presented in Chapter 1; An investigation of the changing land use pattern on agricultural labour is presented in Chapter 4 of this dissertation.

development. In contrast only one of ten farming villages in the survey reported the same.

The results of the reduced probit model presented in Table 8A.5 confirm that that sea-based villages are more likely to suffer from unemployment than inland creek-based villages. However, the negative and insignificant coefficient on the occupation dummy suggests that they are not any more likely to rank unemployment as a more severe problem facing their village than farming villages.

The positive and significant coefficient on CLSTDST in the reduced ordered probit model suggests that larger villages are more likely to face more severe unemployment than smaller villages. Moreover, those villages located further away from the Bay of Bengal (i.e. farming communities) are less likely to rank unemployment as more problematic than those closer to the Bay. Moreover, villages closer to the shrimp farming cluster are less likely to rank unemployment as more problematic.

While the results underpin the fact that fisher-folk are hit harder than farming communities, the estimated models do not answer the question, why? Two explanations are offered. First, for the past several seasons, wild fry purchases by shrimp farmers have steadily declined as a result of the abundance of hatchery seed. This implies a loss of indirect employment for women who engaged in this economic activity. Moreover, supplemental household income has therefore necessarily fallen. Second, at the time of the survey, the Supreme Court ban on shrimp farming forced all shrimp farmers in the region to halt production. Locally hired labour from adjacent villages for jobs such as pond preparation and other earthworks projects were therefore no longer required. Farming communities engaged in shrimp farm labour were most likely less severely hit by the ban since demand for agricultural labour is relatively constant in the region.[20]

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[20] Based on discussions with agricultural workers.

8.5.6 Poor Health

There has been increasing concern voiced by NGOs over the deteriorating health of local inhabitants as a result of shrimp farm development. Several NGO based studies have suggested that village populations adjacent to shrimp farms face greater exposure to mosquito related illnesses (PREPARE, 1995). These studies argue that shrimp farming has attracted a large number of mosquitoes as a result of the growing number of stagnant ponds. Other studies claim that local inhabitants suffer from skin irritations directly related to exposure to effluent discharge water released into common water ways (TWN, 1997).

In the sample survey of villages, fifty-three percent of the fishing villages reported that they face some type of health problems as a result of shrimp farm development. The health problems reportedly faced by fishing communities include light skin irritation. They believe that this problem is a result of effluent discharge into the near shore areas where they fish. Near shore fishing requires full contact with the water for several hours per day. One observation made by the survey team was that fisher-folk using this method purposely fished near the discharge pipes. The team was told that the pipe made it easier to employ this method of fishing. Also, a concentration of wild fish are found feeding near the discharge pipes since effluent contains particles of unconsumed shrimp feed. In contrast, none of the farming villages reported health problems as a result of the activities of nearby shrimp farms.

The estimation results presented in Table 8A.6 suggest that wealthier fishing communities and those with smaller size families face more severe health risks than poorer fishing villages and villages with larger size families. In fact, the transformed probit coefficient on wealth suggests that given a marginal increase in average village wealth, the probability that poor health is a problem among Kandaleru fishing villages increases by 60 percent. Moreover, a similar finding is confirmed by the transformation of the wealth coefficient in the reduced ordered probit model. A marginal increase in average village wealth will result in a 77 percent probability that villages initially ranking health as the least severe impact will now rank it as the second least severe impact. One possible explanation is that populations enjoying a higher standard of living are less tolerant toward illnesses.

Transformation of the reduced probit model coefficient on average household size suggests that for a marginal increase in average household size, the probability that villages face health related problems falls by 28 percent. In addition, as distance increases between villages and shrimp farming clusters, problems of poor health become more severe. This is evident from the positive and significant coefficient on the associated variable in the reduced ordered probit model.

8.6 Conclusions

Probit and Ordered Probit analyses reveal that both socio-economic and demographic characteristics of villages and shrimp cluster characteristics help explain the existence and severity of social impacts faced by rural inhabitants. While the explanatory variables included in the econometric models are not an exhaustive list, they do however, jointly explain village responses at ten percent significance or better for each of the preferred models. Therefore, bias arising from omitting important variables is not readily apparent. Nonetheless, additional factors would undoubtedly improve the robustness of the results.

Village location and occupational status are crucial factors in explaining the existence of social impacts faced by village communities in the probit models. Similarly, the two variables are often significant in explaining the relative severity ranking of village impacts in the ordered probit models. In fact, either location or occupation were found to be significant determinants in explaining both the existence and severity of social impacts for each impact, excluding well water salinity. Policy makers, therefore ought to be aware that the problems faced by rural populations are far from uniform across villages. Any compensation or regulatory schemes must be devised along village location and occupational lines.

The relative average wealth of villages is an important determinant of whether villages face problems of well water salinity and whether they are bothered by health problems. Wealth does not play a significant role in identifying or assessing the existence or severity of the other investigated impacts. Poorer villages are more likely to face well water salinity problems. Wealthier villages, however, are more likely to complain of health related illnesses. Unfortunately, data limitations do not enable further investigation of the relationship between average household wealth and these two impacts.

Finally, it is clear from the results that some minimum distance between shrimp farm clusters and villages is needed in order to protect cultivable land from salinity. First, 73 percent of the sample villages report it to be a problem that they face. Second, the average rank given to this problem is high at 4.11. Regulation of this kind could most likely improve the overall well-being of the region's inhabitants.

Appendix 8A

Empirical Results of Estimated Probit & Ordered Probit Models

Table 8A.1

Factors Explaining Well Water Salinity Impacts

WSALIN	**Ordered Probit**	**Reduced Ordered Probit**	**Probit**	**Reduced Probit**
AVG HOUSEHOLD WEALTH	-0.806 (-1.091)		-1.875* (-1.816) [-0.541]	-2.001** (-2.101) [-0.609]
VILLLAGE SIZE: POPULATION	-0.004* (-1.707)	-0.004** (-2.087)	-0.005 (-0.970) [-0.005]	
AVERAGE HOUSEHOLD SIZE	-0.104 (-0.309)		-0.309 (-0.586) [-0.089]	
TOTAL CULTURE AREA: CLUSTER	-0.003* (-1.793)	-0.002** (-1.923)	-0.005* (-1.745) [-0.001]	-0.003 (-1.596) [-0.001]
DIST. BETWEEN CLUSTER & VILL	-0.846 (-1.397)		-1.733 (-1.572) [-0.500]	-1.722* (-1.778) [-0.523]
DIST. BETWEEN VILLAGE & SEA	0.009 (0.358)		-0.035 (-0.801) [-0.010]	
OCCUPATION DUMMY	0.776 (1.053)		-0.985 (-0.761) [-0.242]	
CONSTANT, ε_1 ε_2 ε_3 ε_4	3.816** (2.041) -2.894 (-1.611) -2.310 (-1.284) -0.875 (-0.494)	2.708** (4.218) -1.840 (-3.471) -1.311 (2.673) -0.0460 (-0.102)	-0.985 (-0.761)	3.823** (2.596)
N=25				
MEAN			0.650	0.650
PSEUDO-R^2	0.162	0.102	0.398	0.331
LOG LIKELIHOOD	-30.93	-33.15	-9.44	-10.49
ITERATIONS	3	4	5	4
CHI2(#)	11.99	7.54	12.46	10.37

t-ratios in parenthesis; *dF/dx* evaluated at the mean in brackets for probit models; **significant at 5 percent level; *significant at 10 percent level, # is the number of explanatory variables used in the model; Interpretation of ordered probit coefficients and their signs: a positive (negative) and significant coefficient of an explanatory variable suggests that villages with a larger quantity or value of the explanatory variable are *more likely (less likely)* to suffer from negative consequences of the given social impact. Interpretation of *dF/dx* and their signs: the probability that water salinity is a problem falls (if the sign is negative) increases (if the sign is positive) by [(*dF/dx*)*100] for a finite increase in the explanatory variable, evaluated at its mean.

Chi-squared (Chi2) tests suggest that the joint explanatory power of each model is greater than zero at the ten percent significance level. The Likelihood Ratio (LR) Test suggests that both reduced form models are preferred to the general specification.

Table 8A.2
Factors Explaining Agricultural Land Salinity Problems

AGSALIN	Ordered Probit	Reduced Ordered Probit	Probit	Reduced Probit
AVG HOUSEHOLD WEALTH	0.036 (0.051)		-0.512 (-0.453) [-0.105]	
VILLLAGE SIZE: POPULATION	-.0002 (-0.101)		-0.001 (-0.044) [-0.000]	
AVERAGE HOUSEHOLD SIZE	0.371 (1.078)	0.375 (1.215)	0.352 (0.706) [0.073]	
TOTAL CULTURE AREA OF CLUSTER	0.003* (1.834)	0.003* (1.868)	0.007 (1.590) [0.001]	0.005* (1.667) [0.001]
DIST. BETWEEN CLUSTER & VILL	0.376 (0.646)		0.125 (0.155) [0.025]	
DIST. BETWEEN VILLAGE & SEA	0.014 (0.518)		0.126 (0.069) [0.026]	0.139 (0.959) [0.031]
OCCUPATION DUMMY	-0.670 (-0.936)	-0.870* (-1.825)	0.816 (0.035) [0.197]	1.103 (0.598) [0.293]
CONSTANT, ε_1	-0.541 (-0.316)	0.074 (0.057)	-2.781 (-0.811)	-2.81 (-0.956)
ε_2	1.083 (0.633)	0.469 (0.363)		
ε_3	2.276 (1.271)	1.654 (1.216)		
ε_4	3.378 (1.876)	2.727 (1.961)		
N=25				
PSEUDO-R^2	0.105	0.094	0.221	0.196
LOG LIKELIHOOD	-33.28	-33.67	-11.55	-11.6
ITERATIONS	3	3	6	5
CHI2(#)	7.82	7.02	6.54	5.82

t-ratios in parenthesis; *dF/dx* evaluated at the mean in brackets for probit models; **significant at 5 percent level; *significant at 10 percent level, # is the number of explanatory variables used in the model;

Chi2 tests suggest that only the joint explanatory power of variables in the reduced ordered probit model is greater than zero at the ten percent significance level. The joint explanatory power of the variables in the other models is no different from zero at the ten percent significance level or better. The Likelihood Ratio test suggests that both reduced form models are preferred to their respective general models.

Table 8A.3
Factors Explaining Impacts from Blocked Access to Water Body

ACCESS	Ordered Probit	Reduced Ordered Probit	Probit	Reduced Probit
AVG HOUSEHOLD WEALTH	0.204 (0.255)		-1.597 (-1.012) [-0.212]	-1.493 (-0.976) [-0.234]
VILLLAGE SIZE: POPULATION	-0.001 (-0.554)	-0.001 (-0.577)	0.114 (1.391) [0.002]	0.011* (1.699) [0.001]
AVERAGE HOUSEHOLD SIZE	-0.084 (-0.227)		0.673 (0.823) [-0.037]	
TOTAL CULTURE AREA: CLUSTER	-0.004 (-0.238)		-0.001 (-0.485) [0.000]	
DIST. BETWEEN CLUSTER & VILL	1.021 (1.453)	1.015* (1.604)	1.362 (1.111) [0.206]	0.944 (0.825) [0.148]
DIST. BETWEEN VILLAGE & SEA	0.011 (0.401)		0.034 (0.694) [0.01]	
OCCUPATION DUMMY	1.342* (1.752)	1.172** (2.406)	4.272 (1.515) [0.980]	2.596** (2.706) [0.618]
CONSTANT, ε_1	-0.333 (-0.180)	-0.432 (-0.577)	-6.899 (-0.934)	-2.058 (1.501)
ε_2	0.868 (.479)	0.946 (1.261)		
ε_3	1.664 (0.902)	1.831 (2.31)		
N=25				
PSEUDO-R^2	0.135	0.132	0.570	0.538
LOG LIKELIHOOD	-26.87	-28.14	-5.91	-6.98
ITERATIONS	3	3	7	6
CHI2(#)	8.38	8.77	15.72	16.32

t-ratios in parenthesis; *dF/dx* evaluated at the mean in brackets for probit models; **significant at 5 percent level; *significant at 10 percent level, # is the number of explanatory variables used in the model;

The Chi2 Tests suggest that the joint explanatory power of variables in the reduced probit model (model 2) is greater than zero at the ten percent significance level; The variables in both general and reduced ordered probit models have a joint explanatory power greater than zero at the five percent significance level. The LR Test suggests that both reduced form models are preferred to their respective general specifications.

Table 8A.4
Factors Explaining Fodder & Fuelwood Collection Problems

FODFUL	Ordered Probit	Reduced Ordered Probit	Probit	Reduced Probit
AVG HOUSEHOLD WEALTH	-1.716 (-1.069)		-0.752 (-0.715) [-0.267]	
VILLLAGE SIZE: POPULATION	0.008 (1.515)		0.001 (0.40) [0.000]	
AVERAGE HOUSEHOLD SIZE	(0.584) (0.064)		0.276 (0.55) [0.098]	
TOTAL SIZE: ~~SHRIMP CLUSTER~~	-0.014 ~~(-1.400)~~	-0.065** ~~(-2.231)~~	-0.003 ~~(-1.18)~~ [-0.001]	-0.004** ~~(-1.91)~~ [-0.001]
DIST. BETWEEN CLUSTER & VILL	-4.453** (-2.089)	-15.816** (-1.990)	-0.787 (-1.04) [-0.280]	-0.691 (-0.95) [-0.244]
DIST. BETWEEN VILLAGE & SEA	0.206** (2.264)	0.401* (1.896)		
OCCUPATION DUMMY		-7.788** (-2.220)		
LOCATION DUMMY			Predicts Perfectly	Predicts Perfectly
CONSTANT, ε_1 ε_2 ε_3 ε_4	5.983 (1.498) -5.457 (-1.398) -3.635 (-0.977)	26.995** (2.101) -25.716 (-2.010) -19.905 (-2.162)	0.249 (0.11)	1.257 (1.366)
N=25				
PSEUDO-R^2	0.613	0.777	0.194	0.175
LOG LIKELIHOOD	-9.66	-5.57	-13.17	-13.46
ITERATIONS	8	9	4	4
CHI2(#)	30.70	38.89	6.33	5.74

t-ratios in parenthesis; *dF/dx* evaluated at the mean in brackets for probit models; **significant at 5 percent level; *significant at 10 percent level, # is the number of explanatory variables used in the model;

Chi2 Tests suggest that the joint explanatory power of variables in the ordered probit models are greater than zero at the one percent level; the joint explanatory power of variables in the reduced probit model is significant at ten percent whereas the joint explanatory power of variables in the general probit model is no different from zero. The Likelihood Ratio Test suggests that the reduced form of each general model is preferred to the general specification.

Table 8A.5
Factors Explaining Unemployment Impacts

UNEMPL	**Ordered Probit**	**Reduced Ordered Probit**	**Probit**	**Reduced Probit**
AVG HOUSEHOLD WEALTH	-0.466 (-0.536)		-0.715 (-0.663) [-0.058]	
VILLLAGE SIZE: POPULATION	0.007** (1.990)	0.006** (2.108)	0.010 (0.921) [0.001]	0.008 (1.330) [0.004]
AVERAGE HOUSEHOLD SIZE	-0.386 (-0.782)		-0.763 (-0.664) [-0.031]	
TOTAL SIZE: ~~SHRIMP CLUSTER~~	0.001 ~~(0.084)~~			
TOTAL CULTURE AREA: CLUSTER			0.001 (0.033) [0.000]	
DIST. BETWEEN CLUSTER & VILL	1.822* (1.835)	1.559* (1.672)	0.569 (0.357) [0.041]	
DIST. BETWEEN VILLAGE & SEA	-1.414** (-2.052)	-1.357** (-2.163)	-0.438 (-1.216) [-0.032]	
OCCUPATION DUMMY	-6.515 (-0.260)	-6.130 (-0.574)		
LOCATION DUMMY			1.404 (0.629) [0.087]	3.020** (2.321) [0.794]
CONSTANT, ε_1	8.488 (0.339)	6.681 (0.663)	0.055 (0.010)	2.870* (-1.704)
ε_2	-6.638 (-0.264)	-4.939 (-0.491)		
ε_3	-5.227 (-0.208)	-3.670 (-0.364)		
ε_4	-3.829 (-0.152)	-2.369 (-0.233)		
N=25				
PSEUDO-R^2	0.515	0.502	0.608	0.478
LOG LIKELIHOOD	-15.98	-16.88	-6.71	-9.36
ITERATIONS	12	11	9	6
CHI2(#)	34.01	33.98	20.86	17.17

t-ratios in parenthesis; *dF/dx* evaluated at the mean in brackets for probit models; **significant at 5 percent level; *significant at 10 percent level, # is the number of explanatory variables used in the model;

Chi2 tests suggest that the joint explanatory power of variables in each of the models presented above is greater than zero at the five percent significance level. The LR test indicates that both reduced models are preferred.

Table 8A.6
Factors Explaining Reported Health Problems

HEALTH	Ordered Probit	Reduced Ordered Probit	Probit	Reduced Probit
AVG HOUSEHOLD WEALTH	2.866* (1.891)	2.146** (1.903)	1.640 (1.467) [0.110]	1.742* (1.876) [0.604]
VILLLAGE SIZE: POPULATION	-0.003 (-1.384)		(-0.001) (-0.480) [-0.000]	
AVERAGE HOUSEHOLD SIZE	-2.064** (-2.266)	-1.465** (-2.600)	-1.458* (-1.694) [-0.097]	-0.809** (-2.050) [-0.281]
TOTAL SIZE: SHRIMP CLUSTER			-0.002 (-0.764) [-0.000]	
TOTAL CULTURE AREA: CLUSTER	-0.009 (-0.275)			
DIST. BETWEEN CLUSTER & VILL	2.633** (2.181)	2.268** (2.059)	1.777 (1.466) [0.119]	0.915 (1.197) [0.317]
DIST. BETWEEN VILLAGE & SEA	-1.401 (-1.548)	-1.413 (-1.535)	-0.288 (-1.242) [-0.019]	
OCCUPATION DUMMY	3.433 (1.305)	2.831 (1.516)	Predicts Perfectly	Predicts Perfectly
CONSTANT, ε_1	5.415 (1.339)	3.129 (1.431)	3.871 (1.185)	0.852 (1.394)
ε_2	-1.614 (-0.466)	0.032 (0.061)		
ε_3	-0.664 (-0.191)	0.973 (0.502)		
N=25				
PSEUDO-R^2	0.617	0.593	0.470	0.241
LOG LIKELIHOOD	-11.97	-13.05	-8.655	-12.72
ITERATIONS	10	9	8	4
CHI2(#)	38.21	38.03	15.36	8.09

t-ratios in parenthesis; *dF/dx* evaluated at the mean in brackets for probit models; **significant at 5 percent level; *significant at 10 percent level, # is the number of explanatory variables used in the model;

Chi2 tests suggest that the joint explanatory power of variables in each of the above models is greater than zero at the five percent significance level. The LR test suggests that the reduced ordered probit model is preferred to the general model whereas the general probit is preferred to its reduced specification.

Appendix 8B

Collinearity Amongst Explanatory Variables

The degree of association between variables is determined to identify potential problems of multi-collinearity. Simple diagnostic tests reveal that the following variables are correlated to the extent that if simultaneously included in either Probit or Ordred Probit models, they would pose statistical problems. First, CLSTSZ and WSA are positively and almost perfectly correlated. Second, TPONDS, TFARMS, TCORP are also positively and significantly correlated with each other and significantly correlated with CLSTSZ and WSA at one percent. The correlation coefficient for each is above 0.90. Therefore, in specifying the general model either CLSTSZ or WSA is used and TPONDS, TFARMS, TCORP are dropped.

Similarly, since the population of the village, POP and the number of households per village, VILSZ are also found to be positive and significantly correlated with each other, we include only VILSZ to represent the size of each village. Finally, WEALTH was found to be almost perfectly correlated with the proportion of *pucca* houses in a village, PUCPROP. As information is available for the proportion of *pucca* houses for each of the twenty-six villages surveyed and only the asset wealth for twenty villages, PUCPROP is used as a proxy for village asset wealth (see Appendix 8C for the methodology used to construct a village wealth index).

Appendix 8C

Constructing An Index of Wealth for Coastal Fishing & Farming Villages

In this section we present the methodology used to construct an index of average household wealth for each of our sample of twenty-six villages. The wealth index essentially takes into account the value of major structural and occupational assets in each village and is used as an explanatory variable in assessing the determinants of social impacts ranked by household heads in our village survey.

For each of the seventeen fishing villages surveyed data were available on the total number of fishing crafts and nets owned by village members and the total number of *pucca* houses constructed in each village. Data on fishing crafts and nets/tackle are further categorised by the type of fishing craft (i.e. country crafts or mechanised boats) and type of net (i.e. simple nets and/or complex nets with multiple hooks attached). In addition, data on the purchase/construction cost (imputed from number of man-hours of labour in addition to the purchase price of raw materials) for each type of boat and net are obtained from the Bay of Bengal Program office in Madras, India (FAO, 1991). Construction costs per household for *pucca* housing is obtained from the same source. From these data we construct an index of aggregate village wealth (in terms of assets) from the following equation,

$$(1) \qquad W_n = \sum B_{n,i} C_i^1 + \sum N_{n,j} C_j^2 + \sum H_{n,k} C_k^3$$

where $i=1,2,3; j=1,2,3; k=1,2; n=1,2,...N$

where W is the index of wealth for village n; $B_{n,i}$ is the total number of boats of type i owned by village n; C_i^1 is the average cost in Indian Rupees for a boat of type i; $N_{n,j}$ is the total number of nets of type j owned by village n; C_j^2 is the average cost in Indian Rupees for a net of type j; $\sum H_{n,k}$ is the total number of households in village n, C_k^3 is the cost to construct a dwelling of type k. If $k=1$, the dwelling is primarily constructed from mud and straw; If $k=2$, the dwelling is a *pucca* house or dwelling with a cement foundation. C_2^3 is the subsidised cost in Indian Rupees needed by the household to pay the Indian government to construct a dwelling of this type; N is the total number of villages surveyed; $i=1$ indicates that the boat is a simple three to four log *kattumaram* (catamaran), $i=2$ indicates that the boat is a large *kattumaram* with an out board motor; $i=3$ indicates that the boat is a mechanised *navas* fishing craft; $j=1$ indicates that the net is a small mesh monofilament gillnet used primarily by small *kattumarams*, $j=2$ indicates that the net is a large mesh gillnet used by large *kattumarams* and mechanised *navas*; $j=3$ indicates that the net is a shore seine net.

The wealth variable used in our analysis is simply an average household wealth index which is defined as follows for each village community,

(2)
$$\omega_n = \frac{W_n}{\sum H_{n,k}}$$

where ω_n is an index of average household assets in village n and $\sum H_{n,k}$ is the total number of households in village n. Details on the types of fishing craft, fishing gear, coastal dwellings and their asset value are obtained from the Bay of Bengal Programme of the Food and Agriculture Organization (FAO, 1991:10) and presented in the following table.

Table 8C.1
Primary Assets Owned by Fishing Communities in Andhra Pradesh

Village Asset	Variable	Asset Value (*Rupees*)	Brief Description
Fishing Crafts	B_i	C^1	
small *kuttumaram*	I=1	3,500	5-6 meters long, made from 3-4 logs, 3 crew
large *kuttumaram*	I=2	8,000	8+ meters long, made from 5-6 logs, 4 crew
navas	I=3	30,000	8+ meters long, large mechanised craft, 6 crew
Fishing Gear	N_j	C^2	
small gillnet	j=1	13,000	11 panels, 14 cm nylon mesh nets
large gillnet	j=2	33,000	50-60 panels, 10 cm mesh nets made from nylon; hooks attached to each panel.
shore seine net	j=3	2,200	1-2 cm cotton mesh nets
Housing	H_k	C^3	
hut	k=1	1,000	dwelling made from mud and straw
pucca house	k=2	22,000	cement foundation; single or multi-floor dwellings

Data on the average household assets for farming villages are unavailable. However, the proportion of *pucca* houses in each fishing village was found positively and significantly correlated ($r=0.47$; $p=0.02$) with the average household asset value, ω_n. The proportion of *pucca* houses in each farming village is therefore used as an equivalent index to proxy the average value of household assets in each farming village. This assumption enables the use of a wealth index in the analysis.

Appendix 8D
Changes in Predicted Probabilities

Table 8D.1 presents the transformed coefficients of only the significant ordered probit results. It follows the transformation method programmed by Long (1997), but mechanically presented in Greene (1996). The value of each cell in the table is interpreted as: *the probability of falling into that rank category given a marginal change in the explanatory variable.*

Table 8D.1
Marginal Effects of Significant Ordered Probit Coefficients, %

	1	2	3	4	5	6
WWSALIN						
VILSZ		0.01	0.02	0.01	-0.02	-0.02
WSA		0.02	0.05	0.03	-0.05	-0.06
AGSALIN						
WSA		-0.05	-0.04	-0.04	0.08	0.05
OCCUP		8.6	7.9	7.8	-14.4	-9.9
ACCESS						
CLSTDST			-18.7	-12.7	-8.7	40.2
OCCUP			-25.0	-17.1	-11.6	53.7
FODFUL						
CLSTSZ	0.18		-0.07	-0.01		0.00
CLSTDST	58.1		-21.7	-35.7		0.66
OCCUP	78.5		-29.3	-48.3		0.89
UNEMPL						
VILSZ		-0.05	0.02	0.02	0.01	0.01
CLSTDST		0.00	0.00	0.00	0.00	0.00
SEADST		0.00	0.00	0.00	0.00	0.00
HEALTH						
WEALTH	-77.2	27.8	4.0	0.4		
HHSZ	50.2	-47.4	-2.6	0.26		
CLSTDST	-0.01	0.01	0.00	0.00		
OCCUP	-158.0	149.6	8.2	0.82		

Part IV

Conclusion

Previous to this dissertation there was a lack of comprehensive knowledge of the productive efficiency of the shrimp farming sector and the extent of the sector's impact on rural inhabitants. This was due to a lack of quantitative data to objectively examine a variety of hypotheses regarding the shrimp industry and the sector's interaction with rural people. The primary and secondary data assessed in this research provide the first analysis of the efficiency of the shrimp farming sector and its socio-economic and environmental impacts on rural communities. Overall, the farm level production data are not dissimilar to shrimp farms operating elsewhere in India. Secondly, the village impact surveys are comprehensive in that they cover twenty-six villages in the Kandaleru region and are indicative of what many villages throughout India's shrimp farming belt may be facing. Together, they provide the first comprehensive study on Indian shrimp farming and its impacts. Moreover, the results of each investigative area may provide policy makers with some direction with which to regulate brackishwater shrimp aquaculture along sustainable lines. This section therefore extracts the most important conclusions reached in the dissertation.

The prevailing literature states that shrimp farming has displaced traditional agriculture and thereby displaced agricultural labour. It also suggests that the amount of labour needed for paddy farming is greater than that of shrimp farming. This research supports both claims. However, the extent to which agriculture or the rural labour force is being displaced is of little significance overall. First, merely 0.2 percent of cultivable agricultural land has been converted to shrimp farms in Nellore district. Secondly, an average of approximately 300 person-days of labour per water spread hectare per year are needed for shrimp culture as opposed to 346 person-days of labour per sown hectare in paddy cultivation per year. The difference is significant. However, when considering the fact that the majority of shrimp farms were constructed on non-agricultural land, it is clear that shrimp farming is providing significant employment opportunities for rural inhabitants. However, the analysis presented in Part III of this dissertation suggests that while a proportion of rural inhabitants enjoy employment through shrimp farming, the population as a whole suffer from an array of socio-economic and environmental impacts.

There are six negative social impacts of shrimp farming that are of significant consequence to rural inhabitants located adjacent to shrimp farming clusters: village well water salinity, agricultural land salinity, restricted and/or blocked access to public access areas for income generating activities and/or fodder and fuelwood collection, unemployment or underemployment problems as a result of lay-offs and poor health due to exposure to shrimp farm effluent. The health issue is not surprising considering the finding that across Kandaleru farms, feed inputs—which pollute the aquatic environment—are used in excess and ultimately are discharged as effluent in areas used by fisher-folk. Each impact, however, was found to vary in its overall severity. Moreover, the importance of each impact was also found to vary by a village's primary occupation and/or location. It is clear that the problems faced by rural populations are far from uniform across villages. While identification of impacts is one important contribution of this research, assessing each impact's severity on rural villages is another. The Social Impact Index serves as a mechanism to assess the severity of impacts facing Kandaleru villages.

The Social Impact Index reveals that well water salinity, blocked access, and agricultural land salinity are moderately severe impacts facing the region. Problems of unemployment and fodder and fuelwood collection are of lesser consequence for the region. However, both the Social Impact Index and Ordered Probit and Probit analysis reveal that occupation and location are key determinants of the degree to which villages are facing a particular social impact. While fishing villages identified blocked access to the beach, agricultural land salinity and poor health as very severe, moderately severe, and problematic problems respectively, the remaining impacts were of little consequence. Farming villages identified fodder and fuelwood collection problems from a lack of available natural resources (due to shrimp farm construction or blocked access) as a moderately severe problem. Well water salinity was found to be problematic. The remaining impacts were found to be of little overall consequence to villages categorised by occupation, despite the fact that a few individual villages in each category may have claimed the opposite.

Probit and Ordered Probit analyses also affirms that both socio-economic and demographic characteristics of villages and shrimp cluster characteristics help explain the existence and severity of social impacts faced by rural inhabitants. Location and/or occupation were found to be significant determinants in explaining both the existence and severity of social impacts for each impact, excluding well water salinity. It is clear that compensatory or regulatory schemes formulated by Indian policy makers must be devised along village location and occupational lines. Moreover, the relative average wealth of villages was found to be an important determinant of whether villages face problems of well water salinity and whether they are bothered by health problems. Poorer villages were found to be more likely to face well water salinity problems. Wealthier villages, however, were more likely to complain of health related illnesses. Finally, it is clear that some minimum distance between shrimp farming clusters and villages is needed in order to protect cultivable land from salinity. Regulation of this kind could most likely improve the overall well-being of the region's inhabitants.

Shrimp cultivation can easily pollute the environment. Farmers increase intensity levels by raising stocking densities and feed inputs per unit pond area. Over-feeding in conjunction with high stocking densities invariably leads to pollution of the pond environment and to shrimp disease. Shrimp disease forces an early harvest or at worst, destroys the entire crop. Either way, the polluted pond water discharged from the farm into a common waterway has two major consequences. First, it is used as fresh intake water by downstream shrimp farmers. This infects the downstream farmer's crop. Second, pollution of common waterways has dire consequences to plant and fish species and to marine biodiversity. Moreover, there are spill-over effects to the local inhabitants who rely on these species as a source of food or income generating activities. Naturally, the Indian Supreme Court voiced its concern in its decision to ban the shrimp farming sector. However, this decision appears to be a bit harsh. The analysis of shrimp farm efficiency in Part II revealed several important findings that may help to effectively regulate Indian shrimp farming along sustainable lines.

Parametric and non-parametric approaches were used to measure shrimp farm efficiency and discuss issues of scale economies in this sector. The PFA approach enabled a first attempt at assessing which managerial practices improve efficiency (i.e. mechanisation, a smaller pond size, smaller farm size) and those that reduce it (i.e. over-feeding, downstream location). The DEA research identified and confirmed the existence of scale economies in shrimp farming. In fact, an inverse relationship was found to exist between farm size and efficiency. Moreover, a trade-off between scale efficiency and pure technical efficiency was found to exist in brackishwater shrimp farming.

A regulatory framework limiting the intensity of shrimp production could provide a pareto improving solution to all parties concerned. Reducing culture intensity implies a general scaling down of factor inputs. This places less stress on the internal pond and natural aquatic environments. If large and corporate farms scale down factor inputs, they are likely to reap cost saving and profit raising benefits. Moreover, the incidence of disease and polluted effluent discharge could be reduced from minimising intensive culture practices. The stress currently placed on the ecosystem's natural carrying capacity would invariably be reduced and therefore ease the many concerns raised by environmentalists. However, regulation unfairly constrains the large (and intensive) farms that are consistently operating efficiently. However, until better technology and managerial practices become known, it may be in the best interest of the Indian nation to limit the intensity of culture operations in brackish water shrimp aquaculture.

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