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Aviation Meteorological Services, Sea Water Desalination, Ornamental Fish Culture, and Lobster and Crab Fattening: Economic Benefits, Project Impact Analyses and Technology Policy

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At MoES, a number of professionals provided invaluable help. Dr Parvinder Maini provided excellent guidance as the Project Reviewer and Advisor. Others who were part of the project advisory group included Dr Purnima Jalihal, Mr Raju Abraham, Dr Kirbhakaran at NIOT; Mr M.K. Bhatnagar, Mr Ajit Tyagi, and Mr S. Chadha at IMD and AAI; Dr Sanjeevan, Dr Anil, and Dr Shivaji at CMLRE; and Dr S. Prabhakar and Dr Nancy J. Anabel at BARC and MSSRF

Foreword

India has a long maritime history and a vast coastline to match, stretching some 7,500 km and touching the Arabian Sea, the Bay of Bengal and Indian Ocean. Its territory includes more than 1,250 islands, and its Exclusive Economic Zone runs some 2.02 million sq. km. The sea has tremendous influence on the physical and meteorological conditions of the country. The vast coastal and offshore environment supports a wide variety of marine ecosystems rich in diversity and economic activities.

The Indian Ministry of Earth Sciences (MoES) is mandated to provide the nation with the best possible services in forecasting monsoons and other weather and climate parameters, ocean states, earthquakes, tsunamis, and other earth phenomena through well integrated programmes of research in atmospheric sciences using remote sensing and other technologies. MoES was established by the Government of India in 2006 by merging different meteorological agencies and the Ocean Development Department.

MoES offers a range of services to industries and end users that are related to its research and its forecasting. This NCAER report supported by MoES seeks to understand the perspectives of the main stakeholders who use these services and to estimate the economic benefits of five specific services being provided by MoES. These five services are (1) meteorological services to the aviation sector provided by the India Meteorological Department (IMD in New Delhi), (2) technology for desalination of marine water, (3) lobster fattening, and (4) crab fattening provided by the National Institute of Ocean Technology (NIOT in Chennai), and (5) marine ornamental fish culture provided by the Centre for Marine Living Resources & Ecology (CMLRE in Cochin).

The study estimates the economic value of aviation meteorological services and examines the current cost recovery model of the Airports Authority of India (AAI). The Report finds that AAI should earmark 6 per cent of the Route Navigation & Facility Charges, an important part of the airport charges that airlines pay, to IMD for the provision of meteorological services to the aviation sector. Among the operational models for provision of meteorological services to the aviation sector, international evidence suggests that many countries that experimented with commercialization have now moved back towards more focused public service provision.

The report includes an outline of a policy for desalination technologies and a methodology to assess the impact of the introduction of MoES programmes and projects in both island and mainland district economies. The study points out that any technology policy on desalination should address the issues of energy and ecology apart from basic processing costs. The Report details two examples involving a co-generation unit attached to a power plant and a stand-alone desalination plant as case studies for the application of this technology policy. The study includes assessment of the other three services. Finally, the study examines the likely impact of desalination and ornamental fishing activities on the island economies of Lakshadweep, Agatti, and Kavaratti. Using input-output analysis, the report suggests that the direct and indirect impact of MoES desalination programmes and backyard hatcheries in these coral islands could result, after gestation, in a substantial increase in the gross domestic product and employment generation on these islands.

This comprehensive study of the Impact Assessment and Economic Benefits of Weather and Marine Services provided by MoES would not have been possible without the cooperation of a number of individuals and organisations listed in the box on the study team. IMD, NIOT, and CMLRE have all contributed immensely in shaping the final study. NCAER would like to thank these individuals for meeting its team members and contributing to the completion of this report. I am grateful to Mr R Venkatesan for leading the study.

New Delhi
September 25th, 2012

Shekhar Shah
Director-General
NCAER

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Abbreviations

AAI	Airports Authority of India
AERA	Airport Economic Regulatory Authority
ATF	Aviation Turbine Fuel
CAGR	Compound Annual Growth Rate
CER	Certified Emission Reduction
CMLRE	Centre for Marine Living Resources and Ecology
ECAA	European Common Aviation Area
ED	Electro Dialysis
EU	European Union
GDDP	Gross District Domestic Product
GDP	Gross Domestic Product
GSDP	Gross State Domestic Product
HDPE	High Density Polyethylene
HPCS	High Performance Computing System
ICAO	International Civil Aviation Organization
IDIs	In Depth Interviews
IMD	India Meteorological Department
MWH	Mega Watt Hours (1000 Kilo Watt Hours)
LTTD	Low Temperature Thermal Desalination
MED	Multi Effect Distillation
Met	Meteorological
MFI	Meteo France Instruments
MoA	Memorandum of Agreement
MoES	Ministry of Earth Sciences
MoU	Memorandum of Understanding
MSF	Multi Stage Flash Distillation
MSSRF	MS Swaminathan Research Foundation
NCTPS	North Chennai Thermal Power Station
NGO	Non-governmental Organisation
NIOT	National Institute of Ocean Technology
NMHS	National Hydro Meteorological Services
NMS	National Meteorological Services
NSSO	National Sample Survey Organisation
OBC	Other Backward Classes
PLF	Plant Load Factor
PPP	Public–Private Partnership
RNFC	Route Navigation Facility Charges
RO	Reverse Osmosis
RVR	Runway Visibility Range
SC	Scheduled Caste
SHG	Self-help Group

SPV	Special Purpose Vehicle
ST	Scheduled Tribe
Tot	Terms of Trade
TTPS	Thoothukodi Thermal Power Station
VC	Vapour Compression
WPI	Wholesale Price Index

Executive Summary

- Research in atmospheric science for understanding the variability of weather and its forecast in all ranges including the extreme weather conditions is one of the important components of major research and development activities being carried out in the Ministry of Earth Sciences (MoES). Similarly, understanding of ocean state and its forecasting, using remote sensing and other technologies, as well as application of marine biology, form another set of important activities of MoES.

- Of the numerous services related to ocean state and atmospheric science offered by MoES, this report focuses on five specific services being provided by three different units under MoES, namely National Institute of Ocean Technology (NIOT), India Meteorological Department (IMD), and Centre for Marine Living Resources & Ecology (CMLRE). The five services and the corresponding units undertaking them are as follows:

  1. Meteorological services to the aviation sector: IMD
  2. Technology for desalination of marine water: NIOT
  3. Lobster fattening: NIOT
  4. Crab fattening: NIOT
  5. Marine ornamental fish culture: CMLRE

A. Aviation Meteorological Services

- Meteorological services play a crucial role in the successful operation of aviation industry. This is because safe aviation requires accurate forecasting of the upper atmosphere over an entire national airspace as well as precise forecasts in the neighbourhood of airports. The primary objective of meteorological (Met) services for national and international air navigation is to contribute to the safety, economy, regularity, and efficiency of air navigation achieved by supplying accurate information on the conduct and development of air navigation.
- *Operational Models for Provision of Met Services: International Evidence:* The evidence-based analysis suggests that it is not prudent to commercialise provision of Met services. IMD should continue to enjoy monopoly rights in provision of Met services. Many countries which experimented with commercialisation have moved away from it towards a more focused public service mission. The intent has been to maximise social benefits rather than to maximise revenue collection. For instance, the Single European Sky concept overcomes the restriction of regulatory hurdles by eliminating ownership restrictions of airlines thereby reaping economies of scope in obtaining Met services for aviation. Thus, IMD should continue to enjoy monopoly rights in provision of meteorological services.
- *Economic Value of Meteorological Services:* We have used the economic analysis for an estimation of the fair share of Route Navigation Facilities Charges (RNFC) that can be apportioned to IMD for provision of meteorological services. The first one is known as the “Evidence-Based Approach”. The World Bank found that when

meteorological services provided by the public sector, Meteoagency, in Russian Federation, were commercialised, it could cover 15 per cent of National Meteorological Services' budget.

- Extrapolating the evidence to Indian conditions it emerges that AAI should earmark Rs 85 crore at current RNFC rates (in 2011–12 prices) or 6 per cent of RNFC to IMD for provision of Met services. The second step is the cost recovery approach. It validates the findings from evidence-based approach. A levy of 6 per cent of RNFC towards Met services may not affect the "fair returns" (12 per cent return on gross block or capital employed) for AAI at current levels of RNFC levy.
- RNFC now levied as per technical norms may not be an appropriate levy per cost recovery principles and could be brought down significantly. AERA, the regulatory agency, could examine this afresh.
- *World Meteorological Organisation (WMO) also provides guidelines to recover Aeronautical Meteorological Services cost.* WMO suggests recovery from composite RNFC and landing fees for providing IMD's Met services.
- *The major findings from the informed stakeholders' field survey* on qualitative aspects of provision of meteorological services are: Weather forecast information provided by IMD is quite useful to take quick and correct decisions for flight planning as well as for flight safe landing and takeoff. The weather forecast provided by IMD in severe weather conditions are adequate. The weather information is disseminated now-a-days over internet and telephone. Online briefing system over the IMD website has also been adopted. The informed stakeholders' suggestions to IMD have been listed in the report to improve the accuracy of forecasts.
- Network analyses have been carried out to study the effect of emerging trends in the demand for air travel from the international as well as domestic travel passengers. Implications of adding more nodes to the air traffic, likely trends in cargo passenger movements, etc. have been analysed in the study.

B. National Institute of Ocean Technology – Technology Policy for Desalination

- *One of the major projects undertaken by NIOT is on desalination.* The scope of this study is confined to evolving a technology policy and to examine the impact of setting up LTTD stand alone plants in islands and LTTD cogeneration plants linked to power plants (conceived on the basis of heat recovery from the reject water of condensers) in this framework.
- *Desalination of sea water to fill up the demand-supply gap:* At present, around 690 billion cubic meters (BCM) of surface water and 390 BCM of ground water is available in India. Total annual demand for water from all sectors such as irrigation, household use and industry in India is expected to increase from 600 BCM in 2010 to 1180 BCM by 2025. This would represent virtually the entire utilisable water resources in the country not being able to meet the required demand. Desalination can be a solution to this gap in demand and supply of water across all sectors.
- *Evolving a technology policy on desalination*: Any technology policy on desalination should address the issues of energy and ecology. More energy intensive processes generally mean more carbon dioxide emissions; ecological effects arise if the existing ecosystem is disturbed and in the process livelihood of fishermen is affected.
- Basically there are two types of conventional desalination processes: (i) thermal desalination and (ii) sea-water reverse osmosis (RO). Under thermal desalination

process, three different technologies are used: multi-stage flash desalination (MSF), multi-effect distillation (MED), and low temperature thermal desalination (LTTD).

- Low Temperature Thermal Desalination (LTTD) is one process that uses the availability of a temperature gradient between two water bodies or flows to evaporate the warmer water at low pressure and condense the resultant vapour with colder water to obtain freshwater.
- While ocean, with its temperature variation across its depth, presents one such scenario of two water bodies, a coast-based thermal power plant discharging huge amounts of condenser reject water into the nearby ocean represents an alternative application.
- In the former case LTTD is a stand-alone desalination plant (Lakshadweep case study) while in the latter case LTTD is a cogeneration thermal desalination unit.

Case study of stand-alone LTTD plant at Kavaratti

- Based on the case study of Kavaratti, the process of cost recovery needed to earn 12 per cent Internal Rate of Return (IRR) on investments in LTTD technology, works out to 75 paise per litre of desalinated water. While the ecological cost in using the LTTD technology is negligible, the environmental cost works out to a meager 0.23 paise per litre of desalinated water . The overall cost works out to 75 paise per litre of desalinated water.
- It is understood from the study that LTTD technology is the only way forward in coral islands, in spite of higher energy consumption vis-à-vis RO on account of the following reasons:
  1. LTTD does not involve the discharge of brine solution into the sea, hence is eco-friendly. This helps to protect the interests of the vulnerable fishermen in the area, major stakeholders in the island economy.
  2. The technology is maintenance free, and can be easily operated by less skilled labour.

Case study of Thoothukodi LTTD co-generation unit

- *Based on the project cost, operating and financial expenses for the LTTD process, the estimated price of desalinated water per litre from the project in Thoothukodi to yield 12 per cent IRR works out to 10 paise.*
- Environmental cost due to the higher energy consumption over the RO technology desalination process works out to a mere 0.05 paise per litre.
- LTTD process does not have any adverse ecological side effects.
- In the case of Thoothukodi power projects, adoption of RO process for desalination would entail a huge ecological cost as the existing eco-system would be affected. The fishing sector would be affected, the effect of which has been estimated as the potential loss in GDP of the district due to use of (ecologically) sub-optimal RO process.
- The total value of output of fishing activity in Thoothukodi district for the year 2009–10 at factor cost has been estimated at Rs 473.67 crore. However, at market prices,

the value of output of fishing is Rs 832.24 crore. The difference between the market prices and factor cost of fish output is accounted by trade and transport (Rs 365.90 crore) and net indirect taxes (– Rs 7.34 crore).

- According to the information provided, if RO technology is used, which includes the consequent discharge of brine, the fish catch would decrease by about 30 per cent. The loss on account of adopting RO technology in Thoothukodi has been assessed at Rs 142.10 crore in fish output, Rs 58.50 crore in trade activity and Rs 51.28 crore in transport activity.
- This is the direct impact on the economy of Thoothukodi district and is purely on account of brine discharge following the adoption of RO technology. However, decrease in output of the district in fishing, trade and transportation will also indirectly affect other industries due to the inter-industry linkages in the economy. For estimating the indirect impact, the static Leontief model (based on Leontief inverse model, is used.
- For Thoothukodi district as a whole, the fall in output of the district will be 1.2 per cent if direct and indirect effects are taken into account as a result of brine discharge due to introduction of RO technology in Thoothukodi. In absolute terms, the direct loss will be Rs 251.87 crore and indirect loss will be another Rs 120.50 crore, bringing the total loss to Rs 372.37 crore.
- The loss in output translates to Gross District Domestic Product loss of Rs 316 crore. If the district power plants set up around 20 million litres per day plants to cater to all power plants as well as meet the drinking water requirements for the township, the ecological cost per litre works out to 43 paise per litre. The ecological cost of 14 paise per litre is also enormous, even if the catch is affected very marginally by 10 per cent.
- Even if the processing cost of desalination using alternative technologies is lower than the bench-mark cost of 10 paise for LTTD, the overall cost of desalination, considering the composite processing, ecological, and environmental cost would be far lower if LTTD process is adopted.
- Since the private sector does not pay for negative externalities, it would resort to the widespread adoption of RO process, unless the technology policy is put in place or adoption of LTTD process is incentivised.

C. National Institute of Ocean Technology – Lobster and Mud-Crab Culture

- The study also briefly examines NIOT's efforts directed at evolving a technology to culture lobsters and mud-crab in open sea environment which is more an application of marine biology.
- The object of this study is to examine whether this marine biology application can augment the income of fishing households involved and to examine ways to scale up the experiment for an increased penetration.
- However, NIOT's main interest is to ensure that sufficient seeds are available for breeding to the juveniles' stage through an application of bio-technology. This process is still in the development stage.

Lobster Culture

- Lobster culture ventures in India involve collection of lobster juveniles from nature (wild) and growing them to the required size, unlike the practice in other countries such as Vietnam, Phillipines etc., where collection of larvae is done to metamorphose them into early juvenile stage. Unlike other lobster fishing countries, there is no regulation on the size of lobsters caught in India resulting in about a third of our commercial-catch being undersized juveniles. These juveniles can be utilised for lobster culture/fattening for value addition.
- Moreover, fattening of big size lobsters can also be done for two to three months to increase their "grade" in the live export trade. Lobster fattening using NIOT-developed technology initiative can be a lucrative occupation according to the target households chosen for experimental implementation in Thoothukodi district.
- However, the target households feel that the training imparted by NIOT though relevant, may not be useful as the households would require handholding and uninterrupted support for adoption of technology. Besides they would need to access funds to service their working capital needs as well as funds to acquire cages.
- At present only around 1 per cent of households involved in fishing activities in two villages of Thoothukodi district have taken to this technology. To scale up the project implementation efforts and to disseminate technology without any threat to loss of IPR, NIOT may have to enter into an exclusive Memorandum of Agreement (MoA) with NGOs like M S Swaminathan Research Foundation (MSSRF) who have extensive hands-on experience in forming self-help groups as well as project implementation experience for a widespread adoption along Indian coastal areas.

Crab Fattening

- In Andaman and Nicobar Islands the potential for crab fattening exists. Prior to the Tsunami in December 2004, the Islands had adopted the NIOT developed crab fattening activity. Inhabitants are eager that the activity be re-initiated. The activity was abandoned after the Tsunami in 2004. Islanders expressed the need for an intervention by NGOs to provide the necessary support in technology adoption as well as in accessing funds.
- In 2006, MSSRF started an initiative with the objective of providing income-earning opportunities and fostering sustainable livelihood security of the fishing communities who were affected badly by Tsunami. It is a micro-credit programme through self-help groups (SHGs) for the fishing communities to revive and diversify the livelihoods.
- If NIOT enters into an MoA with MSSRF to re-initiate the activity in Andaman and Nicobar Islands and replicate it in calm seas elsewhere along India's sea-coast, then there is a feasibility of wide-scale adoption of NIOT-developed practices in India. Such an agreement can be a win-win game for both the organisations.

D. Centre for Marine Living Resources and Ecology (CMLRE) - Marine Ornamental Fish Culture

- Marine ornamental fish is caught wild in the seas. However, if these species are directly exported after their wild collection they tend to exhibit very high mortality rates. In order to export them to other countries or to transport them within the country, they need to be cultured and developed up to a certain stage. At the same time breeding or rearing of marine ornamental fishes in hatcheries is equally important and feasible in coral islands in order to sustain long-term export growth. In other words, application of marine biology principles and practices in hatching developed by the Centre for Marine Living Resources and Ecology (CMLRE) is the central theme examined in this section.
- CMLRE's role in ornamental fish culture is one of the main areas of research, where application of marine bio-technology is used for farming marine ornamental fish.
- The need of the hour is to scale up the project from an experimental 14 members' initiative to the full Islands' initiative. Roughly 150 fishing families in Agatti and around 200 fishing families in Kavaratti can set up back-yard hatcheries to augment their family income.
- Scaling up of the activities by CMLRE can be accomplished in three ways:
    1. Recognise the need to develop the project in public/private sector mode on commercial lines and recognise that both CMLRE as well as the Ministry of Earth Sciences would need a separate legal entity for domiciling all the assets (mainly tanks) and the cash flows of the project for the purpose of securitisation. Also, to fulfil the need of having a focused management of the project, CMLRE could set up a Special Purpose Vehicle (SPV) for the project. This would have a separate legal entity for entering into specific contracts, agreements with the panchayats, with the private sector groups, etc.
    2. The alternative approach would be the simple option of forming an SHG in each island and authorising them, collectively, to receive funds from CMLRE or seek the state administration's intervention as has been successfully done in the introduction of LTTD technology for drinking water supply in these islands.
    3. Can request the national level NGOs to facilitate SHGs' formation on a commission basis.

E. Likely Impact of Desalination and Ornamental Fishing Activities on Island Economies of Lakshadweep, Agatti, and Kavaratti

- The choice of LTTD desalination technology and the initiation of marine ornamental fishing hatcheries complement each other. Thus the economic benefits of developing ornamental fishing hatcheries as well as the introduction of LTTD technology need to be analysed in an integrated fashion.
- The evolution of I–O models for Agatti and Kavaratti Islands permits us to estimate the direct and indirect impacts of MoES programmes in coral islands. An introduction of LTTD technology as well as backyard hatcheries to export ornamental fish can result, after the gestation period, in an increase of Lakshdweep's domestic product by 12 per cent. The increase in Agatti and Kavaratti Islands' domestic product would be around 22 per cent and 18 per cent, respectively. Total employment in Lakshadweep would increase by 5 per cent, and that for Agatti and Kavaratti would increase by 16 per cent and 12 per cent, respectively.

Introduction

Chapter 1

Introduction

Atmospheric science for understanding the variability of weather and vulnerability of the economy to extreme weather conditions form an important component of the research activities in the Ministry of Earth Sciences (MoES). Similarly, understanding of ocean state, application of remote sensing and other technologies, as well as application of marine biology, form another set of important activities of MoES.

Government of India established MoES in 2006 by merging the meteorological agencies and ocean development department. The main objective of MoES is to provide the nation with forecasts on monsoons and other weather/climate parameters, ocean state, earthquakes, Tsunamis and other phenomena related to earth systems through well-integrated programmes. A wide range of activities under such services contribute to various societal benefits in the areas of weather, living and non-living resources (fishery advisory, poly-metallic nodules, gas hydrates, etc.), coastal and marine ecosystems, and climate change. These services have significant economic and social benefits to key stakeholders such as individuals, firms, industry sectors and national bodies.

Of the numerous services related to ocean state and atmospheric science offered by MoES, this report focuses on five specific services being provided by three different departments and autonomous bodies under the ministry. MoES has been taking several initiatives through technology development or research and development (R & D) activities in each of these areas. The main objective of this report is to assess the economic benefits of these services based on the data collected from primary surveys and structured interviews. A review of national and international literature on these theme areas as well as a review of methodological issues adopted by regional and multilateral agencies in assessing economic benefits of meteorological services were carried out initially. The five services and the corresponding bodies undertaking these services being considered in this report are mentioned below.

- Meteorological Services to the Aviation Sector: IMD
- Technology for Desalination of Marine Water: NIOT
- Lobster Fattening: NIOT
- Crab Fattening: NIOT
- Marine Ornamental Fish Culture: CMLRE

The following government departments or autonomous bodies under MoES are involved in providing these technologies and services:

1. India Meteorological Department (IMD)
2. National Institute of Ocean Technology (NIOT)
3. Centre for Marine Living Resources and Ecology (CMLRE)

1.1 India Meteorological Department (IMD)

IMD serves five major sectors, viz. (1) aviation, (2) agricultural meteorology, (3) hydro meteorology including shipping and fisheries, (4) public services, and (5) climatology including R & D and international cooperation through its cost centres of general analysis / forecasting, telecommunications, data processing, observational network, and climatological services.

In India, meteorological services for aviation sector are provided by IMD under MoES through Airports Authority of India (AAI). According to an MOU signed between IMD and AAI in 2006, approximately Rs 18 crore (1997–98 prices) is to be paid by AAI to IMD per annum. The amount was to be revised every two years based on annual rate of inflation published by RBI. AAI collects RNFC; which includes a component for meteorological services provided by IMD to AAI.

1.1.1 IMD's Meteorological Services to the Aviation Sector

Meteorological services play a crucial role in the successful operation of aviation industry. This is because safe aviation requires accurate forecasting of the upper atmosphere over an entire national airspace as well as precise forecasts in the neighbourhood of airports. The primary objective of meteorological services for national and international air navigation is to contribute to the safety, economy, regularity and efficiency of air navigation achieved by supplying accurate information on the conduct and development of air navigation.

This study attempts to assess the economic value, reliability, timeliness as well as adequacy of weather forecast information through a field survey. An economic analysis to arrive at the appropriate levy IMD can claim from AAI for its meteorological services has also been attempted at.

1.2 National Institute of Ocean Technology

The National Institute of Ocean Technology (NIOT) was established in 1993 as an autonomous society under the Ministry of Earth Sciences, Government of India. NIOT is managed by a Governing Council and the Director is the head of the Institute. The major objective of establishing NIOT was to develop reliable indigenous technology to solve the various engineering problems associated with harvesting of non-living and living resources in the Indian Exclusive Economic Zone (EEZ), which are about two-thirds of the land area of India.

One of the major projects undertaken by NIOT is on desalination. The main area of focus of the group is the utilisation of the ocean resources to find alternative technologies for fresh water and renewable energy. Currently the group is working on three specific areas—fresh water production using low temperature thermal desalination (LTTD) process, energy production using two distinctly different processes, and Ocean Thermal Energy Conversion (OTEC) and Wave Energy.

NIOT also has a technological group with the following main areas of concern:

- Lobster fattening
- Mud crab fattening
- Coastal pollution awareness campaign
- Assessment of drinking water quality

The scope of this study is confined to evolving a technology policy and to examine the impact of setting up of LTTD stand alone plants in Islands and LTTD cogeneration plants linked to power plants (conceived on the basis of heat recovery from the reject water of condensers) in this framework. The study also briefly examines efforts directed at evolving the technology to culture lobsters and mud-crab in open sea environment.

1.2.1 Technology Policy for Desalination of Marine Water

Desalination technology refers to the process of converting sea water to desalinated water suitable for human consumption, irrigation, power plants and other industrial use. Desalination process is also used on ships and submarines. Most of the modern interests in desalination technology are focused on developing cost-effective ways—not only processing costs but also environmental and ecological costs—of providing fresh water for human and power plant/industrial use. There are basically two types of conventional desalination processes: thermal desalination and (sea water) reverse osmosis (RO). Thermal desalination process consists of three different technologies: Multi-stage Flash Distillation (MSF), Multi-effect Distillation (MED), and Low Temperature Thermal Desalination (LTTD).

The study aims at developing a policy for the choice of technology. The criterion evolved for comparison and choice is the composite cost per unit output comprising of base cost (which is the process cost to yield a 12 per cent IRR), environmental cost (cost due to a higher specific energy consumption valued in terms of certified emission reduction) and ecological cost (cost due to the disturbance of the eco-system measured as the difference in the GDP of project catchment area captured through the Leontief–Inverse). This study compares NIOT's LTTD thermal desalination technology with RO process which can cause irreversible ecological damages to the existing marine eco-system in the above framework. The direct and indirect effects of the introduction of LTTD technology in the Island of Kavaratti has been traced through construction of the island's specific Input–Output (I–O) Tables as well as computations of the Islands' gross domestic product (GDP). The ecological damages an RO plant could cause to Thoothukodi ecosystem instead of the proposed clean LTTD plant has also been analysed through construction of Thoothukodi district specific I-O Table and its Leontief-inverse.

1.2.2 Lobster Fattening

Lobster culture/fattening generally involves collection of lobster juveniles from nature and growing them to the required size in cages or tanks. NIOT has developed a viable marine biological process for fattening lobsters in sea-cages in the coastal areas of Tamil Nadu on an experimental basis. Floating sea cages are designed and deployed in selected locations along the southeast coast of India to grow spiny lobsters. There can be a substantial improvement in earnings of coastal fishermen with the implementation of this scheme. This has been computed based on a field survey. However, with penetration levels of only around 1 per cent of households involved in fishing due to high capital and working capital requirements, the project needs a scaling up of NIOT efforts which are discussed in the study. We have to develop sufficient number of seeds to meet the requirements of culture technology. The biotechnology development to achieve this is still at the development stage. Thus, no attempt has been made to compute economic benefits.

1.2.3 Crab Fattening

Crab fattening is essentially stocking and rearing of soft shelled crabs in smaller impoundments for a certain period till the shells are hardened and they flesh out. These 'hard' crabs are locally known as "mud" (meat) and fetch three to four times higher price compared to soft crabs. Crab fattening is the most popular method of crab culture since the culture period is short and profitable, when enough stocking material is assured. Crab seeds are available in the nature in all sizes. Juvenile crabs can be collected from estuaries, lakes, backwaters, creeks, mangroves, and salt water lagoons by using bamboo traps, lift nets, or scissor nets. The mud crabs live in marine as well as brackish environments. The marine biological process developed by NIOT and the project implemented in the Andaman Islands is not operational since the 2004 Tsunami. Although crab fattening cannot be as lucrative as lobster fattening, yet in Andaman Islands households are interested in the re-initiation of the programme perhaps with hand-holding efforts of an NGO. As the biotechnology application to produce sufficient number of seeds to meet the requirements of culture technology is still in an early development stage no economic analysis has been carried out.

1.3 Centre for Marine Living Resources and Ecology

Centre for Marine Living Resources and Ecology (CMLRE) under MoES has been organising, coordinating, and promoting ocean development activities in the country which include mapping of the living resources, preparing inventory of commercially exploitable living marine resources, their optimum utilisation through ecosystem management, and R & D in basic sciences on marine living resources and ecology. Ecosystem based predictive models are used for explaining probable changes in marine ecology from climatic or other man-made global changes.

Marine Living Resources Programme (MLRP) envisages sustainable utilisation of marine organisms based on an ecosystem approach. Marine organisms provide us with food (fishery), varieties of materials and bioactive molecules and also mediate processes that help remove atmospheric CO_2. Global changes, both anthropogenic and natural, impact the living organisms directly or through disturbances to their natural habitat. One of the key objectives of MLRP is to understand the ecosystem, explain its physical, chemical, and biological attributes and model the complex interactions amongst these attributes that maintain the systems in a steady state. Using such models, it will be possible to predict how the ecosystems, including the biological components, may respond to global changes.

Technology development programme under MLRP has succeeded in the operationalisation of marine ornamental fish trade from Lakshadweep. It is expected that commercialisation of this activity can generate income and employment to the islanders, without disturbing the delicate ecosystem of the island. Hatchery production of ornamentals through green technology is also an energy-efficient production system which is best suited to islands. Further, MLRP have also succeeded in producing black pearls from the black-lip pearl oyster, *Pinctada margratifera,* found in Andamans. The pearls produced at this hatchery unit are quality pearls with a golden colour and is expected to fetch around US$ 50 to 80 per pearl.

Commercialisation of pearl production in Andamans will be taken up during the Twelfth Plan period.

1.3.1 Marine Ornamental Fish Culture

Ornamental fishing is one of the main areas where research has been carried out by CMLRE. This is an area where application marine biotechnology is used for faming marine ornamental fish. Keeping colourful and fancy fishes known as ornamental fish is one of the oldest and most popular hobbies in the world. The growing interest in aquarium fishes has resulted in steady increase in aquarium fish trade globally. The present study focuses on marine ornamental fish culture in the islands, especially an initiative by CMLRE in Agatti island of Lakshadweep. A field survey and focused group interviews have been conducted as part of the study to assess the economic impact of taking up ornamental fish culture as a livelihood option among the people of the islands.

Species of marine ornamental fish are caught wild in the calm and clear seas. These cannot survive in aquariums under normal conditions unless they are hatched and nurtured to improve immunisation to normal conditions. In order to export them to other countries or even to transport them within the country, they need to be cultured and developed up to a certain stage. Thus breeding and rearing of marine ornamental fishes in hatcheries is important in order to sustain long-term export growth. CMLRE, under the Ministry of Earth Sciences, is working in the area of farming of marine ornamental fish in the coral islands of Lakshadweep. The process of wild collection of ornamental fish and farming in hatcheries is being developed by CMLRE and the technology has been used in Agatti island of Lakshadweep. This study estimates the likely direct and indirect impact of the initiative after the gestation period, if adopted by the interested 150 households in Agatti and 200 interested households in Kavaratti Island through an analysis of I-O Table as well as the Leontief-inverse.

Aviation Meteorological Services

Chapter 2
Aviation Meteorological Services

Aviation sector is an important client of hydromet services because safe aviation requires accurate forecasting of the upper atmosphere over an entire national airspace, as well as accurate forecasts in the neighbourhood of airports. Among the most useful data types, upper-air sounding poses a particular issue, as it is one of the most expensive meteorological (Met) service functions. For instance, an inadequate Met services provision in Europe and Central Asia (ECA) affected aviation safety (World Bank Case Study 2008).

In designing the structure of this chapter various components as listed below were conceived:

- Aviation sector in the Indian economy
- Overview of Met services provided to aviation sector
- Should IMD have monopoly rights in providing Met services?
- Economic value of evidence-based approach of IMD's Met services to aviation sector:
  1. Evidence-based costing approach
  2. Cost recovery modules
- Met services to aviation sector are a derived demand. Typically meteorological services are not used on their own but in conjunction with other 'product/services'. As a result, the demand for meteorological services is based on the demand for these related 'product/services' and hence are demand driven.
  1. Aviation as a network industry
  2. Herfindahl Index Analysis
  3. Passenger/cargo market share vis-à-vis passenger/cargo market growth rates analysis.
- Qualitative survey results – suggestions for improvements in delivery of Met services.
- Summary/recommendations

2.1 Air Transport – India

In India, air transport is one of the important modes of transport, especially for long-distance and business travel, accessing difficult terrains, and for transporting high value and perishable commodities mainly on account of speed and saving of time. India has major provinces that compare with prominent nations in Europe necessitating long distance intra-country travel for business, family and pilgrimage purposes. Besides, remotely connected areas such as the North-East are linked to the mainland mainly through air-transport. India is a leading exporter of high value items such as finished diamonds, gems, and jewellery and perishables such as cut flowers. India, in the last decade, has emerged as one of the top ten countries in export of commercial services. Obviously air transportation has been and is likely to remain the relevant industry aiding overall economic growth.

2.2 Role of Meteorological Services in Aviation Sector

Meteorological services play a crucial role in the successful operation of aviation industry since safe aviation requires accurate forecasting of the upper atmosphere over an entire national airspace as well as precise forecasts in the neighbourhood of airports. The primary objective of meteorological services for national and international air navigation is to contribute to the safety, economy, regularity, and efficiency of air navigation achieved by supplying airline operators, flight crew members, air traffic service units, search and rescue services, airport management, and others concerned with the conduct and development of air navigation.

2.3 Economic Value of Meteorological Services

We attempt to examine the economic value of meteorological services provided by IMD to aviation sector in this report. We also assess the reliability, timeliness and adequacy of weather forecast information through a field survey. We attempt to examine the accessibility of the information and readiness of key stake holders in using these. We then assess valuation of these services from the perspective of the provider as well as users. We have tried to understand stakeholders' needs and their requirements of weather services in addition to the existing ones.

The study also makes an attempt to identify the evidence-based propositions drawn from the available international literature on the impact of meteorological services to aviation sector and analyses the major issues related to these provisions in the Indian context.

2.4 Methodology

This section has two components:

1. A descriptive research design involving quantitative information from stakeholders (Section 2.5)
2. An analytical research design on the air transport sector and the associated Met services sector linked to aviation.

The network analysis and its applications have long played an important role in issues related to information theory, cybernetics, the study of transportation systems, and the planning and control of research and development projects. We adopt this analysis to study issues corresponding to air transport system, its progress or lack of it. The associated Met services would be obtained as a corollary.

According to theory, the "graph" consists of conjunction points called "nodes", which represent various airports in the country. The nodes are connected through "branches", which represent the route taken by aircraft between airports. And the "network" is considered to be a graph with aircraft flying via its routes/branches. Each nodal point/airport is both the point of origin and the point of destination. The maximal flow depends on the flow of air traffic to that nodal point and each node becomes a part of the network only if there is sufficient demand for air transportation. The network takes only those nodes that lie beyond a specified threshold distance. It is this theoretical background with which the analysis progresses.

The primary purpose and outcome of this analysis has been to derive the nodes that demand greater importance in terms of Met service provisions on the basis of the study of growth of passenger traffic, freight traffic, air traffic and capacity of respective airports, and to understand the behaviour of networking in the aviation sector. In the process we also derive nodes where the growth of air traffic is not likely to peak over a considerable period of time and where automatic weather stations, in our opinion, could serve the interim period till the demand picks up.

2.5 Respondent Group and Study Area

For the descriptive research various types of respondent groups were targeted in this study including:

- Indian Meteorological Department
- Airports Authority of India
- Airline operators and
- Airlines

The stakeholders contacted were Delhi, Lucknow, and Mumbai airports.

2.6 Evolution of Air Transportation in India

India is the ninth largest aviation market in the world at present. In the last decade, domestic air traffic has quadrupled from 13 million to 52 million and international traffic more than tripled to 38 million. A similar trend is observed in the cargo sector. The recent increase in the demand for air transport is evident in the data released by the Directorate General of Civil Aviation (DGCA). The number of passengers carried by domestic airlines during January–November 2011 was 55.03 million as against 46.81 million during the corresponding period of the previous year. Thus the passenger growth rate was 17.6 per cent during 2010–11. India is hovering to be among the top five aviation nations in the world in the next 10 years.

Air transport is a major global industry occupying central position in today's globalised economies. Aviation sector transports a total of 2.5 billion passengers and approximately 50 million tonnes of freight annually. International air freight transportation has increased by 65 per cent in 10 years during 1997–2007. The passenger growth rate is also significantly high. In addition to the direct economic benefits, the continued growth of air transport industry makes global travel accessible to more people.

The rapidly expanding aviation sector handles 2.5 billion passengers across the world in a year; moves 45–50 million tonnes of cargo through 920 airlines, using 4,200 airports and deploys 27,000 aircraft. Today, 87 foreign airlines fly to and from India and five Indian carriers fly to and from 40 countries.

2.6.1 Output Multiplier

Importance of appropriate policy and regional planning for meteorological services is increasingly realised with the passage of time, given the significant contribution from GDP of air transport to the national economy. According to CSO I-O Table of 2003–04, the output multiplier for air transport sector was 2.1 from which we can infer that one unit increase in the output of aviation sector would lead to an additional 1.1 units of output from different sectors including banking, insurance, hospitality, etc.

2.6.2 Aviation: Impact on Tourism, Exports of High Value Items, and Connectivity

Literature shows any hindrance to the aviation sector adversely affects the tourism sector, exports of high value items, etc. In addition, aviation is crucial to India in terms of connectivity since infrastructure cost in rail and road sector is exorbitant. The aviation sector has the capability to connect the remote areas of importance efficiently.

2.6.3 India: The Fastest Growing Civil Aviation Market

Global air transport industry forecast suggests that India will be the fastest growing civil aviation market worldwide by the end of 2020 with about 420 million passengers to be handled by the Indian Airport system which was 140 million in 2010. Such growth prospect poses a number of challenges to the related fronts. The role of IMD becomes more crucial in this scenario.

2.7 Evolution of Meteorological Services for Aviation Sector

In most of the countries, the production and dissemination of meteorological services is undertaken by publicly owned and operated National Meteorological Services (NMSs). In the Europe and Central Asian (ECA) region, it is undertaken by National Hydro Meteorological Services (NHMS). NMSs provide day-to-day weather forecast to households. In addition, they also provide weather forecasts customised to support agriculture, aviation, disaster management, water resource planning management, transport, environmental protection, public health and different other sectors. Globally, aviation sector ranks first for the economic applications served by National Meteorological Services (Table 2.1).

Table 2.1: Rankings of Applications Served by National Meteorological Services

Average Rank (Global)	As Ranked by the Services
1	Aviation
2	Agriculture
3	Disaster Management
4	Water Resource Planning and Management
5	Environmental Protection
6	Mass Media
7	Construction
8	Energy Generation and Supply
9	Marine Transportation
10	Tourism
11	Fisheries
12	Land Transportation
13	Food Production
14	Forestry
15	Insurance
16	Port and Harbour Management
17	Industry
18	Urban Planning
19	Communications
20	Sport
21	Health and Medical Services
22	Leisure
23	Offshore Operations
24	Legal Services
25	Animal Husbandry
26	Commerce
27	Manufacturing
28	Private Meteorological Service Sector
29	Banking and Financial
30	Retail Trade

Source: WMO, "Responses to the Questionnaire on the Role and Operation of NMSs," Preliminary Analysis, 2001.

2.8 NMS Linkages to Ministries and Departments

NMSs are linked to different departments across countries depending upon their utility realisation. For example, NMSs may be associated with Academy of Sciences (Bulgaria), Ministry of Ecology and Natural Resources (Moldova), Ministry of Environment Protection or Natural Resources (Belarus and Georgia), Ministry of Defense (UK), or even Ministry of Emergencies (Ukraine). There are a few countries where NMSs are under Ministry of Agriculture, Water Supply and Forestry (Macedonia) or Ministry of Science Education and

Sports (Croatia). There are exceptions as well. In Russia, NMSs are independent services directly reporting to the prime minister while in Armenia, NMSs are handled by state owned non-commercial organisation. In Albania, NMSs are managed by University of Tirana.

In India, meteorological services for aviation sector are provided by India Meteorological Department under the Ministry of Earth Sciences.

2.9 ICAO Policies: Chicago Convention for International Air Navigation

The requirement for support and standardisation of aviation industry for international travel was first realised by USA in 1944. USA was a major player in international aviation industry. As a result, a convention of civil aviation, popularly known as the Chicago Convention, was drafted. It came into effect in 1947 and was ratified by a number of nations.

Box 2.1: Chicago Convention

- Established International Civil Aviation Organization (ICAO) as an agency of the United Nations.
- Provided mechanism for international agreement on all issues related to civil aviation.
- Has 18 annexes establishing standards for areas such as air traffic control, navigation systems and communication systems.
- Annex 3 of ICAO policies refers to Meteorological Service for International Air Navigation.

Source: WMO Bulletin, April 2009

2.10 Policy Initiations

Open sky policy was adopted by Indian government in April 1990. Till then, government owned airlines had dominated the Indian aviation industry. *Open Skies means unrestricted access by any carrier into the sovereign territory of a country without any written agreement specifying capacity, ports of call or schedule of services. In other words an Open Skies policy would allow the airline of any country or ownership to land at any port on any number of occasions and with unlimited seat capacity. There would be no restriction on the type of aircraft used, no demand for certification, no regularity of service and no need to specify at which airports they would land.*

After realising the spectacular growth potential of civil aviation sector, the following initiatives have been adopted in India through the Eleventh Five Year Plan (2007–2012):

- Model Concession Agreement (MCA) is being evolved to attract private investment and also facilitate smooth execution of air transport projects.
- Airports Economic Regulatory Authority (AERA) has been established in order to create a level playing field and healthy competition amongst all major airports (handling more than 1.5 million passengers per annum); encourage investment in airport facilities; regulate tariffs of aeronautical services; protect reasonable interest of users; and operate efficient, economic, and viable airports.

Ministry of Human Resource Development (MHRD) is examining initiatives to mitigate the acute shortage of qualified personnel, especially pilots and flying instructors. The government has also taken several steps towards structural policy reforms and is coming out with new policies which are liberal and will encourage public–private partnership (PPP).

2.11 Meteorological Services Provided by IMD to Aviation Sector

The major meteorological requirements in the aviation sector are

- current weather observation to all the aeronautical users
- forecasts and warning of meteorological hazards to aviation and
- dissemination of meteorological products to aviators

The crucial weather parameters are

- wind speed and direction
- visibility
- cloud base height
- pressure
- temperature

This information becomes essential in the following weather conditions:

- fog
- dust storm
- turbulence
- lightning
- tornadoes
- tropical cyclones

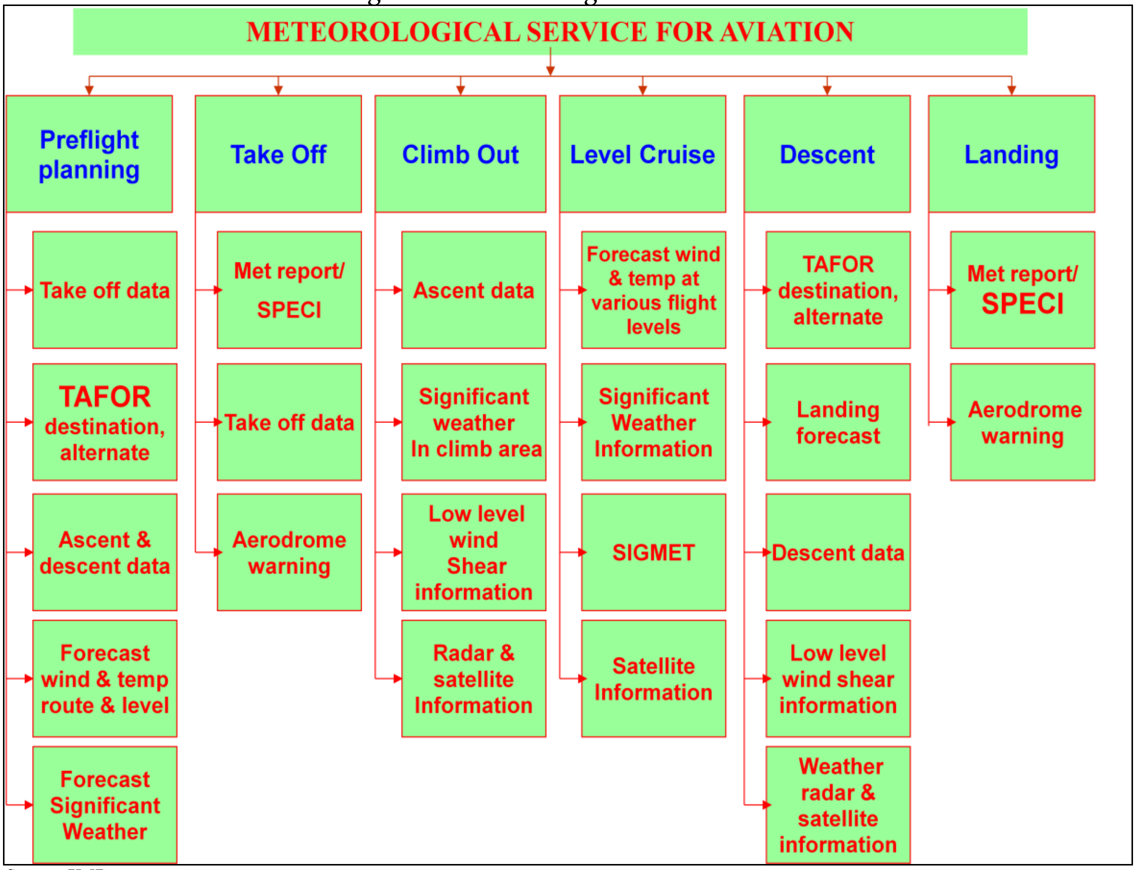
Current weather information as well as weather forecast is essential at each of the six stages of a scheduled flight; namely,

- pre-flight planning
- take-off
- climb out
- level cruise
- descent
- landing

The detailed list of meteorological information, evolved stage, etc. to facilitate aviation operations can be formalised as under.

- As the aviation sector is one of the key meteorological customers, major developments in forecasting provided by IMD have been undertaken for the improvement of meteorological services in aviation sector.
- Worldwide advancement in technology and aircraft design along with constant demand for more efficient and safe operations has motivated IMD to provide increasingly accurate, varied and customer-oriented meteorological products and services, especially for the first 36 hours of the forecast period (Figure 2.1).

Figure 2.1: Meteorological Services for Aviation



Source: IMD

2.12 MET Services to Aviation Sector: Requirement of WMO

For IMD, aviation is an important sector and is required to comply with the requirements of the World Meteorological Organization (WMO). IMD provides aviation services through Aerodrome Meteorological Offices (AMOs) and Aeronautical Meteorological Stations (AMSs) functioning at various airports. The meteorological branches of the Indian Air Force and the Indian Navy also provide meteorological services through airfields controlled by them.

2.13 Field Survey Coverage and Sampling

2.13.1 Coverage

Different types of users of weather services were interviewed for the present study. Users include representatives from Airports Authority of India, pilots, flight dispatchers from domestic and international airlines and airport operators. We have also interviewed IMD officials.

2.13.2 Sampling Design

The selection of respondents was done purposively.

The entire field work of this study was carried out during December 2011 through January 2012. Researchers and senior field executives carried out the interviews.

2.14 Analysis of Issues Confronting Provision of Meteorological Services to Aviation Sector

2.14.1 Issue 1: Should IMD have Monopoly Rights in Provision of Met Services? Evidence-based Analysis

Operational Models for Provision of Met Services: International Evidence

There are several operational models for national meteorological services, such as agencies that provide only public services, agencies that are mix of public sector and commercial enterprise, and those that have created separate, independent commercial services. For example, European weather services have, over the past twenty years or so, experimented with various forms of commercialisation; the U.S. weather service, by contrast, provides all of its products and services to the public at taxpayers' expense. In Europe, the enthusiasm for the development of commercial services has been the strongest in Scandinavia, UK, France and the Netherlands, and the development has encountered varying degrees of success, while German Weather Services (DWD), which experimented with commercialisation, has moved away from it towards a more focused public service mission.

Provision of Met Services: Social Benefits vs Revenue Generation

In India, meteorological services are provided by a government agency, namely IMD. Like many other NMSs in developing countries, apart from its own Met services, IMD accesses free products and services from other leading NMHSs to support their own needs. NMHSs in general have monopoly rights in provision of Met services that can enable the effective reuse of public information by individuals and the private sector. Without a clear separation of their public sector tasks from their commercial interests, it is easy to see how NMHSs may—inadvertently or otherwise—misuse their dominant position in the commercial market for weather, hydro, and climate information. Commercial services are about exclusivity, confidentiality and competition; in contrast, public weather services are about the provision of information to everyone to make timely decisions to protect lives and livelihoods. While the latter depends on the free and open exchange of data and information; profitability of the former depends on restricting information to paying customers. Operating within the competitive market also has an impact on the way NMSs view each other. Traditionally, they have been partners with even the least capable providing a valuable contribution to the global network of observations, and the more capable sharing and exchanging numerical weather prediction products. Hence, the facility of Met services provides a lot of social benefits and in this context there needs to be a free exchange of information.

The Concept of Single European Sky is Different from Chicago Convention

IMD, working under the national banner, performs a broader social role by providing weather services. The issue of whether the Met services provided by IMD should be privatised so that there would be efficiency gain has been raised on several occasions. We argue, if the entire European Union (EU) opts for one sky policy, IMD, in an integrated manner, can continue providing the meteorological services for aviation sector for the entire country. Several nations in EU are even smaller than some Indian states. For example, the smallest nation in EU, Malta, is even smaller than Sikkim, the smallest state in India. European Common Aviation Area (ECAA) helped to connect all these EU nations along with the ten neighbouring countries (Table 2.2).

Table 2.2: Select EU Countries

EU Countries	Area (km²)	Population (million) (2007)	GDP (nominal) in international dollar (million) (2010)

Malta	316	0.4	8,000
Luxembourg	2586	0.5	54,000
Ireland	70000	4.5	204,000
Finland	338000	5.3	239,000
Denmark	43094	5.5	310,000
Hungary	93000	10.0	132,000
Czech Republic	78866	10.5	195,000
Poland	312679	38.1	468,000
United Kingdom	244820	61.7	2,247,000
France	550000	64.3	2,582,000
Germany	356854	82.0	3,315,000

Source: From online resources

EU has the most deeply integrated regional air transport market in the world. In international aviation, still governed by the Chicago Convention and the concept of national sovereignty over airspace, the EU agreement constitutes a radical innovation. All regulatory distinctions between international and domestic services have been abolished. Bilateral air traffic agreements between member countries no longer exist and with national ownership restrictions eliminated, *airlines no longer have a 'nationality'*. Moreover, a common regulatory framework creates a level playing field for competition. In contrast, the more limited open skies agreements used internationally only liberalise the provisions within the framework of the bilateral system and generally do not extent to a harmonisation of sectoral policies.

Economies of size exist in provision of Met services. Economies of size refers to the ability of an industry to function cost effectively by having just one public service provider, which would be IMD in this case.

Implications for IMD

Many countries which experimented with commercialisation have moved away from it towards a more focused public service mission. The accent has been to maximise social benefits rather than revenue collection. Single European sky concept overcomes the restriction of regulatory hurdles by eliminating ownership restrictions of airlines, thereby reaping economies of scope in obtaining Met services for aviation. The evidence based analysis suggests that it is not prudent to commercialise provision of Met services; IMD should continue to enjoy monopoly rights in providing Met services.

2.14.2 Issue 2: Economic Analysis of MET Services to Aviation Sector

Economic Analysis vis-à-vis Financial Analysis

Economic analysis of costs and benefits of providing NMSs is significantly different from their financial analysis. Economic analysis assesses the efforts in the context of the national economy rather than the project entity. For instance, a programme's positive and negative impacts are measured in terms of willingness to pay or in terms of benefits foregone or in terms of disaster funds earmarked to overcome the adverse impact.

Economic analysis differs from its financial analysis counterpart both in terms of identification and evaluation of inputs and outputs and in measurement of cost and benefits. The financial analysis estimates the profit accruing to a programme – the operating entity – or to the programme participant, whereas an economic analysis is expected to measure its effect on the national economy.

Economic Benefits of Meteorological Services

A number of approaches have been developed to estimate the economic benefits of meteorological services. These include the following.

- Market price approach. Market prices are used to measure the benefits of specialised meteorological services when treated as 'private goods'
- Normative or prescriptive decision-making models
- Descriptive behavioural response studies (including user surveys and regression models)
- Contingent valuation models
- Conjoint analysis
- Economic Analysis Guidelines: ADB, World Bank and Planning Commission methodologies

Each of these methods is examined below.

Market Price Approach

Market prices can be used as a measure of the marginal benefits to users of meteorological information, which have 'private good' characteristics. The advantage of market prices is that they explicitly reveal the value that users place on and are willing to pay for particular categories of meteorological information. However, there are limitations to this approach. During the field surveys, airlines insisted that in view of the 'public good' nature of such information, the government should absorb all expenses. Also, airlines pay Route Navigation Facility Charges (RNFC) to the Airports Authority of India which could include a certain portion that is to be paid to IMD for providing Met services. This has not been worked out so far in a scientific manner. Hence, the objective could be to find out the 'fair value' of the meteorological services provided towards aviation by IMD.

Alternatively, another approach can be adopted on the basis of international evidence. In the Russian Federation a Meteoagency (Public–Private Partnership) was established by Rosehydromet which received about 15 per cent of its total funding from this source. Hence, on the basis of this evidence, one can evaluate the plausible proportion to be allocated to IMD for Met services.

Normative or Prescriptive Decision-Making Models

By far the most common set of techniques used to estimate the benefits of meteorological services has been the prescriptive or normative models. This approach views meteorological information as a factor in the decision-making process that can be used by decision makers to reduce uncertainty, to affect savings in fuel to avoid temperature differences that affect fuel consumption or avoid air pockets that cause air bumps. Under this approach the information is directly obtained by airlines from an online service. For instance, only Indigo has a centralised office that continuously briefs pilots with meteorological data (through information provided by IMD) relating to the above mentioned weather conditions. Indigo uses decision making rules to assign some premium value on the timely information provided by IMD. However, the limitation that exists is that the premium is realised by an intermediary—AAI—and not IMD. So the question boils down to what proportion of RNFC should be allocated to IMD.

Descriptive Behavioural Response Studies

Descriptive behavioural response studies can be used to estimate the value of meteorological services by inferring values from the observed behaviour. One set of studies seeks information about the decision-making processes, and about how the meteorological information in these processes is used. The information is obtained in an indirect way through a survey conducted among airlines willing to participate. Responses are sought on decision choices such as whose outcomes are affected by weather and climate, what information is used in making these decision choices and in particular, whether meteorological information is used, and if so, how it is accessed, how it is used to modify decision choices, and what decision changes are made. "Anecdotal" reports, case studies, and user surveys are examples of such an approach that gives a qualitative experience.

Contingent Valuation Models

Contingent valuation is a non-market valuation method used by some analysts in relation to 'public good' meteorological information. The general structure of the contingent valuation study method is as follows. Information is sought from a sample of users of meteorological services, which may be individuals or businesses. An artificial, or hypothetical, market situation is created in which users are asked to indicate, in rupee terms, their 'willingness to pay' for a number of different options. Once the answers on willingness to pay for individual users are obtained, the next step is to aggregate these answers for a measure of the society's willingness to pay. Since this approach is more applicable to meteorological services to general public and not to aviation, we do not adopt this approach. Also, the use of contingent valuation surveys to make estimates of the value of meteorological services is likely to remain controversial. Therefore, we have not tried to elicit such information from our surveys as they can be subjective and misleading.

Conjoint Analysis

This is similar to contingent valuation in that it also uses a hypothetical context in a survey format involving the users of meteorological information. The information sought in conjoint analysis is designed as choices between ranking of preferences for alternatives with multiple attributes. In this case the alternative would be to either provide or not provide meteorological information. This approach is not suitable as airlines need this information and the government is mandated to provide Met services as per ICAO rules.

Hence, as per the economic analysis, we adopt the market price approach to determine the 'fair value' or the proportion of RNFC that should be allocated to IMD for the meteorological services it provides to the aviation sector.

The alternative approach is to base the value based on the evidence approach such as Rosemet's experience in obtaining a "fair value" for their Met services directly from airlines.

Economic Value of Meteorological Services Provided by IMD to the Aviation Sector

IMD is the principal government agency providing meteorological services to AAI at different airports in the country. Until 2006, IMD used to charge AAI for aviation related meteorological services which led to disagreement until agreed guidelines were arrived at to resolve this issue. An MOU was signed between IMD and AAI in 2006 following recommendations of a committee comprising of members from both departments. Approximately Rs 18 crore at 1997–98 prices is to be paid by AAI to IMD per annum. The amount was to be revised every two years based on the annual rate of inflation published by RBI.

AAI collects route navigation and facility charges; this includes a component for Met services provided by IMD to AAI. The other major components of airport charges include landing and parking charges and terminal navigational landing charges. The traffic and non-traffic revenue collected by AAI for the period 2007–11 is shown in Table 2.3.

Table 2.3: Traffic and Non-Traffic Revenue: AAI (Rs lakh)

	2010–11	2009–10	2008–09	2007–08
Traffic revenue				
Route navigation facilities charges	166407	151025	133995	128859
Landing fees	36829	33232	30278	36740
Parking and housing fees	1094	1095	1098	875
Terminal navigational landing charges	28859	27232	24994	23333
Passenger service fee	62631	53873	46955	63875
Non-traffic revenue				
Public admission fees	1452	1587	1466	1961
Trading concessions	36892	33198	29883	28479
Rent and services	25333	23569	22383	13669
Cargo revenue	22928	17625	17794	17051
Income from leasing of airports	104635	94097	82025	74545
Other miscellaneous income	26860	24990	-	-
Total Revenue	**513920**	**461523**	**390871**	**366054**

Source: AAI, Annual Reports

Table 2.4: Percentage of Traffic Revenue – AAI

	% of Traffic Revenue					Four year per cent average of total revenue
	2010–11	2009–10	2008–09	2007–08	Four year per cent average	
Traffic revenue	**100**	**100**	**100**	**100**	**100**	**60.29**
Route navigation facilities charges	56.25	56.68	56.46	50.80	55.05	33.12
Landing fees	12.45	12.47	12.76	14.48	13.04	7.89
Parking and housing fees	0.37	0.41	0.46	0.34	0.40	0.24
Terminal navigational landing charges	9.76	10.22	10.53	9.20	9.93	5.98
Passenger service fee	21.17	20.22	19.79	25.18	21.59	13.07

Source: AAI, Annual Reports

Note: RNFC form 55 per cent of traffic revenue or 33 per cent of overall revenue

Evidence-Based Approach

What is the economic value of Met services that can be used as a guideline to levy the fee?

The World Bank found that when Met services provided by the public sector in Russian Federation were commercialised, it could cover 15 per cent of the budget of NMSs. The international evidence is summed up in the case of Meteoagency (Russian Federation) (Box 2.2).

Box 2.2: Public–Private Partnership: Meteoagency (Russian Federation)

In the Russian Federation, cost recovery is intermediated by a not-for-profit enterprise, Meteoagency, established by RosHydromet. Meteoagency and its branches provide local forecast services at required skill levels to a range of clients. One of the main Meteoagency products is aviation forecasting provided on a negotiated basis to the airlines. Aviation cost recovery revenues are returned to RosHydromet. The measure of success of this model is that RosHydromet receives about 15 per cent of its total funding (or roughly 50 per cent of its commercial services) from this source.

Source: World Bank Working Paper No. 151, 2008

Extrapolating the aviation related services evidence in the Indian context AAI could provide for 15 per cent of IMD budget as Met services fee. This would be the market price approach to an estimation of value of Met services based on international evidence of such an attempt.

As an immediate step we compile the IMD Budget year-wise below (Table 2.5):

Table 2.5: Budget for IMD: Plan and Non-Plan (Rs lakh)

	2010–11	2009–10	2008–09	2007–08
Non–plan budget	24267	26288	19831	21829
Plan budget	32100	31038	43200	30100
Total plan and non-plan budget	56367	57326	63031	51929
Total plan and non-plan actual expenditure	47300	48100	37700	26400
Aviation Met services revenue, expected to cover 15 per cent of IMD budget	8455	8599	9455	7789
Aviation Met services revenue, expected to cover 15 per cent of IMD actual expenditure (plan and non-plan)	7100	7200	5700	4000
RNFC in Rs lakh	166407	151025	133995	128859
Aviation revenue expected to cover 15 per cent of budget as proportion of RNFC in per cent	5.08	5.69	7.06	6.04
Aviation revenue expected to cover 15 per cent of actual as proportion of RNFC in per cent	4.27	4.77	4.25	3.10

Source: IMD

If the international evidence collected is translated to the Indian conditions then 15 per cent IMD budget needs to come from Met services devoted to aviation. *The above computations show that AAI should, therefore, earmark 6 per cent of its RNFC, that is on an average Rs 85 crore as payment for MET services to IMD.* If the actual expenditure (including plan and non-plan) is used as a guideline instead of the budget estimate, then AAI needs to earmark 4.1 – 4.4 per cent of its RNFC that is on an average of Rs 60 crore as payment for Met services to IMD.

Derivation of the economic value of Met services that can be used as a benchmark to charge AAI is the next step.

Cost Recovery Approach

The aim of this approach is to find the appropriateness of RNFC computations by AAI based on weight and distance which is shown in the Annex. This has formed general acceptance from the airlines that pay RNFC to AAI. Our discussions with the Airport Economic Regulatory Authority reveal that the authority has not come out with any consulting paper on the economic rationale of levying RNFC Charges based on weight and distance. The Cost recovery approach allows examining this process assuming that upper bound and lower bound RNFC could be estimated as shown below. RNFC currently form 55 per cent of the traffic revenue or 33 per cent of traffic and non-traffic revenue.

We consider two scenarios as under:

Scenario 1: RNFC should cover 55 per cent of overall AAI cost per aircraft movement.
Scenario 2: RNFC should cover 33 per cent of overall AAI cost per aircraft movement.

Here we make four major assumptions:

1. We use the Gross Fixed Assets' estimates as the investment in AAI. As AAI has been in existence for more than 50 years, the use of Gross Block will overestimate the capital engaged in AAI. However, for want of authentic figures, we use the Net Block plus accumulated depreciation (for 55 years) as the representative Gross Block as shown in AAI financial statements.
2. The discount rate is assumed to be 12 per cent which is equal to the social discount rate cut off for public sector projects.
3. The useful life is assumed to be 25 years.
4. The full cost is obtained as the capital recovery required to earn 12 per cent IRR along with the operating cost per aircraft movement.

Details of computations are shown in Table 2.6.

Performance Parameters

The first step is to list out performance parameters for AAI.

The major performance parameters in terms of passengers, cargo movement year-wise for AAI, compiled from Annual Financial Statements, are as under (Table 2.6):

Table 2.6: Traffic Handled during 2007–08 to 2010–11

Particulars	Unit	International 2010–11	2009–10	2008–09	2007–08
Aircraft movements	Nos.	300197	282204	270345	248538
Passenger movements	Nos.	37907547	34367929	10476147	29818150
Cargo	Tonnes	1496239	1270712	318242	1146745
		Domestic			
Aircraft movements	Nos.	1093663	1048688	1036187	1059091
Passenger movements	Nos.	105577726	89387504	33785990	87067597
Cargo	Tonnes	852197	690900	181176	568233
		Total			
Aircraft movements	Nos.	1393860	1330892	1306532	1307629
Passenger movements	Nos.	143430273	123755433	44262137	116885747
Cargo	Tonnes	2348436	1961612	499418	1714978

Source: AAI, Annual Reports

We extract the total cost of RNFC operations of AAI under scenarios 1 and 2 as under:

Table 2.7: Capital Cost Computation (Rs lakh)

	2010–11	2009–10	2008–09	2007–08
Fixed assets				
(i) Gross block	1223869	1031821	883904	754759
Less: Depreciation	687834	600224	529490	477334
Net block	536015	431597	354414	277424
(ii) Capital work in progress	374752	318594	199643	138012
Investments	97614	92152	85409	46991
Expenses				
Pay and allowances	126377	134421	106060	71163
Other staff cost	39132	26862	36502	23594
Operating expenses	96810	78599	74394	71176
Other administrative and miscellaneous expenses	18662	22086	19281	25813
Aircraft movement numbers	1393860	1330892	1306532	1307629
Total expenses and Gross Block apportioned for RNFC on the basis of RNFC as proportion of traffic revenue	55%	55%	55%	55%
Total expenses and Gross Block apportioned for RNFC on the basis of RNFC as proportion of total revenue	33%	33%	33%	33%
Discount Rate	12%	12%	12%	12%
PV of annuity of Rs 1 per period, for 25 years	7.84	7.84	7.84	7.84
Capital Recovery Factor for 25 years useful life	0.1275	0.1275	0.1275	0.1275
RNFC per aircraft movement	11939	11348	10256	9854
Operating expenses per aircraft movement useful life of 25 years 55 per cent allocation	3820	3248	3132	2994
Capital recovery per aircraft movement useful life of 25 years 55 per cent allocation	6157	5437	4744	4048
Total cost per aircraft movement (RNFC) 55 per cent allocation – Scenario 1	**9977**	**8685**	**7876**	**7041**
Operating expenses per aircraft movements useful life of 25 years 33 per cent allocation	2292	1949	1879	1796
Capital recovery per aircraft movement useful life of 25 years 33 per cent allocation	3694	3262	2846	2429
Total cost per aircraft movement (RNFC) 33 per cent allocation – Scenario 2	**5986**	**5211**	**4726**	**4225**
Operating expenses per aircraft movements useful life of 25 years 100 per cent allocation	6945	5906	5694	5443
Capital recovery per aircraft movement useful life of 25 years 100 per cent allocation	11195	9885	8626	7359
Total cost per aircraft movement (RNFC) 100 per cent allocation	18141	15791	14320	12802
Per cent of Total RNFC cost per aircraft movement (RNFC) required to earn 12 per cent IRR on gross block for AAI (scenario 1)	**83.6%**	**76.5%**	**76.8%**	**71.5%**
Per cent of Total RNFC cost per aircraft movement (RNFC) required to earn 12 per cent IRR on gross block for AAI (scenario 2)	**50.1%**	**45.9%**	**46.1%**	**42.9%**
Per cent of Total RNFC cost per aircraft movement required to cover all AAI operations and earn 12 per cent return on gross block	**152%**	**139%**	**140%**	**130%**

Source: Author's calculations NCAER, 2012

Under Scenario 1, AAI should retain only 77 per cent (on an average) of RNFC charges to earn 12 per cent IRR on Gross Block employed for the purpose.

Under Scenario 2, AAI should retain only 53 per cent (or 46%) (on an average) of RNFC to earn 12 per cent IRR on Gross Block employed for the purpose.

Both Scenarios 1 and 2 show that RNFC could be reduced significantly without hurting returns to AAI. The above analysis says that AAI can easily pay MET charges of Rs 85 crore without affecting its economic and financial viability. In other words, AAI can earmark 6 per cent of RNFC to IMD and yet earn more than 12 per cent IRR.

WMO also provides guidelines to recover Aeronautical Meteorological Services cost which is briefly covered below.

Guide to Aeronautical Meteorological Services Cost Recovery Principles and Guidance, WMO-No. 904, Second Edition, 2007

Early on in the history of aviation, it was decided that in the interests of safety, regularity, and efficiency, each State would provide agreed services for civil aviation such as air traffic services, search and rescue, aeronautical telecommunications, and indeed meteorology, which would be paid for by aviation section usually through the collection of fees for landing at airports in a state (landing fees) and fees charged for overflying a state's territory (en-route charges). In fact WMO suggests recovery from composite RNFC and landing fees for providing IMD's Met services.

The ICAO Convention: To formalise the provision for serving international civil aviation, the Convention on International Civil Aviation was drawn up in Chicago in 1944. This Convention, usually known as the Chicago Convention, is an international treaty and the provisions contained in its articles are legally binding on the government signatories, known as Contracting States, without exception. In particular, unless otherwise officially notified to the International Civil Aviation Organization (ICAO) the Contracting States undertake to comply with ICAO standards. Contracting States have to deliver air navigation services according to ICAO standards.

The Chicago Convention: The Convention has 18 annexes dealing with various aspects of aviation. Annex 3, entitled Meteorological Service for International Air Navigation, deals with meteorology. According to it "The objective of meteorological service for international air navigation shall be to contribute towards the safety, regularity and efficiency of international air navigation."

National charging policy: Given that all service has a cost, any air navigation service provider has to be financed in one way or another for the service it delivers. It is the responsibility of the meteorological authority to take appropriate cost recovery measures for such financing to be organised. The financing systems now observed throughout the world are:

(a) Financing of all or part of the service provision by tax payers are done through the general federal budget;

(b) Financing of all or part of the service provision through specific taxes, part of which is directly allocated to the service provider; the decision to establish such taxes is a sovereign decision of the State and no justification is required;

(c) Financing of all or part of the service provision through user charges (en-route charges or landing fees). It is generally understood that the level of charges is directly related to the service delivered and that it should be justified. In such cases, the service provider is generally requested to justify in a transparent manner the use of the funds allocated from air charges and its costs are carefully watched by the national authorities (this is sometimes called "economic regulation");

(d) Financing of all or part of the service purely under market conditions; this is particularly easy for direct services but may also raise safety issues; and

(e) A combination of the above options.

Cost Basis of Air Navigation Services Charges

ICAO's overall guidelines: ICAO's Policies of Charges advises that when the cost basis for air navigation services is being established, the costs taken into account should be those in relation to all the services for the aviation sector which are listed or provided in accordance with the ICAO Regional Air Navigation Plans and should include any other facilities and services provided at the request of the aircraft operator. Furthermore it suggests that when facilities cease to be provided, the cost of facilities should no longer be included in the cost basis of charges. The cost of administrative and common services should also be taken into account.

Difference between the costs recorded in the accounts of an entity providing air navigation services and costs applied for determining the cost basis of charges.

It is not advisable to rely on the cost accounting of the entity only, when determining the cost basis of charges. This is because the costs of depreciation and cost of capital may be erroneous. Also, cost of capital imputed on the net capital value of the assets of an entity providing air navigation services would normally not be reflected in its accounts but should be included in the cost basis of charges.

Depreciation and amortisation: Depreciation is generally used for tangible fixed assets such as machinery etc. whereas amortisation is used to depreciation in intangible fixed assets such as patents or copyrights. The cost of depreciation is to be included in the annual costs of service concerned. Land is not supposed to depreciate because the usefulness of land does not subside. The cost of installation, non-refundable duties, cost of capital on capital invested in the preoperational phase, and the cost of calibration and testing should also be included. Methods used for calculating the depreciation include the straight line method, reducing balance method and the annuity method. Whichever method is used, it should be applied consistently throughout the life of the cycle.

States experiencing high rates of inflation may need to use alternative approaches to depreciate when, due to national legislation, such inflation cannot be compensated for by the application of the internal cost of capital rates reflecting inflation. An approach that may be used involves adjusting the un-depreciated portion of the original book value of the assets concerned by increasing it by a percentage based on the rate of inflation.

ICAO's guidelines for cost of capital

The cost of capital to be accounted in costs includes:

a) Interest paid to providers of debt capital
b) The appropriate cost of capital applied to equity

The government bond rate or alternative rates in financial markets by enterprise of low risk may be taken as guide.

ICAO's principle of allocation of costs: Services for cost allocation

a) Tower service
b) Radar approach / Terminal area service
c) En-route lower airspace service
d) En-route upper air service
e) Oceanic service

Non-aeronautical utilisation: Met services are shared by many communities. Since no single user determines the level and cost of core activities, the distribution of costs and basis of charging becomes difficult. The proportion of overall Met costs will vary from state to state. It is not possible to indicate any fixed percentage for allocations that would have general validity for this purpose.

The cost of Search and Rescue (SAR) services to be taken into account should be limited to the costs of any permanent civil establishment and personnel maintained for the purpose of providing SAR services and appropriate cost should be then allocated to the civil aviation.

Allocation where facilities serve both the airport and en-route requirements: Considerations should be given in dividing these costs on such a basis that the dual utilisation is reflected. The division is relevant where the costs involved are substantial and there would be a considerable cost burden on any one of the service recipient (the airport or en-route operations). ICAO's policies of charges further recommends that in states where more than one international airport is involved, consideration should be given, where possible, to allocating the costs attributable to airport utilisation between the airports concerned.

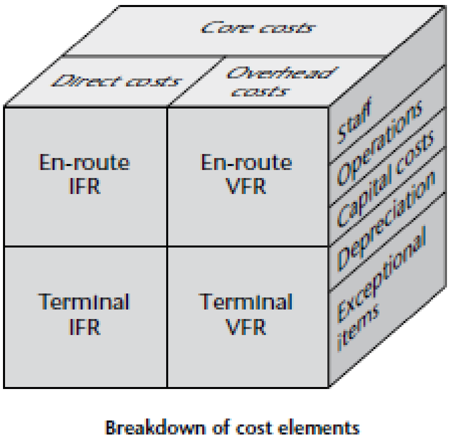
Allocation of total cost to the service locations: The total costs by major item (operating and maintenance costs, administrative costs, overhead, depreciation and cost of capital and taxes) should be allocated to the various service locations of the air navigation services concerned. The cost of allocation exercise should also be allocated to various service locations using the same approach. The type of allocation key applied to a specific cost item or items will depend on the nature of item or items concerned.

Allocation of en-route costs among flight information regions: In the case where en-route services are provided by a state to aircraft outside the Flight Information Region (FIR) in which the facilities concerned are physically located, separation of costs among FIRs may be desired where user charges are to be levied on an FIR basis. This separation should reflect costs incurred by that state in providing the en-route services to the flights operating through the respective FIRs. This problem can be approached by applying ratios based on respective volumes covering two or more FIRs.

General principles: Where meteorological services provided are solely for aviation (direct services), as agreed by the users, national civil aviation authority, meteorological authority (if not the provider) and the National Meteorological Service, the full costs (100 per cent) of providing these services can be recovered from users. In these circumstances, the arrangements for cost recovery may vary from one state to another. However, under the ICAO guidelines, it is necessary to ensure that where a service is solely for an aerodrome the costs are solely recovered from airport fees, whilst if the service solely applies to aircraft in flight (en-route) the costs are solely recovered from air navigation fees. If this clear distinction cannot be made, costs should be apportioned between aerodrome and en-route services. Besides differentiating between airport and en-route utilisation, it may appear necessary to allocate costs among categories of users. A further distinction is made between a service solely for flights operating under Instrument Flight Rules (IFR flights), to ensure that the costs are recovered only from IFR users, and flights solely operated under Visual Flight Rules (VFR flights), whose costs should be recovered from VFR users.

In these cases it becomes necessary to consider an equitable apportionment of the costs of the shared facilities and products (core services). For instance, the central infrastructure and facilities of any National Meteorological Service, such as the WWW observing network and equipment, Global Telecommunication System (GTS) meteorological communications, central administration, central training, central computing facilities, central research and development (RandD), are all used to provide services.

Figure 2.2: Cost Structure



Source: WMO

However, for want of disaggregated data on fixed assets we have not been able to estimate WMO guidelines based cost recovery; we suggest that IMD collect and disseminate such data on inventories of equipment with their current replacement costs at airports as well as estimates of cost especially upper air sounding stations to estimate en-route charges and airport charges needed to recover its investments and earn a 12 per cent IRR.

2.14.3 Issue 3: AAI Levies Overhead Charges for IMD Personnel Posted at Airports. This Can be Inferred from the Significant Differences in the Figures Reported by AAI as Payments for MET Services to IMD and IMD's Receipt of MET Services Fee. Is this economically justified?

In response to this issue, it is critical to understand the concept of economies of scale and economies of scope and size. Economies of scale arise when the quantity of output increases and the average cost falls. The marginal cost of each additional unit is less than the average cost. Such a relationship arises when fixed costs are significantly larger than variable costs of providing meteorological services with public good characteristics. Provision of Met services to aviation sector exhibit significant economies of scale and it would be prudent to realise these benefits.

Economies of scope, on the other hand, refer to the ability of an enterprise to conduct several functions using the same facilities and thereby share the costs of facilities across a number of products. It is apparent that there may be economies of scope in the joint production of basic and special meteorological services by NMS. This is cited by AAI to levy overhead expenses on IMD personnel deployed at airports. Economies of scope exist only if various other services provided by IMD are commercial in nature. Also, given that IMD is a public sector organisation that receives revenue only from aviation despite its services to other sectors (which are non-commercial) mandated by the government, it would be economically incorrect for AAI to levy overhead charges.

Economies of size refers to the ability of an industry to function cost-effectively by having just one service provider, which would be IMD in this case.

2.14.4 Issue 4: Meteorological services received by aviation sector: Is it adequate or needs to be supplemented?

A qualitative survey was conducted to answer the above question. The respondents were:

- Flight Dispatcher, Air India, Delhi
- Flight Dispatcher, Jet Airways, Delhi
- Airport Manager, Jet Airways, Lucknow
- A ground staff from Thai Airlines
- Airlines Operator, Delhi International Airport Limited
- Director-in-Charge, IMD, Lucknow
- Director-in-Charge, IMD, Mumbai

Aviation sector receives the following services from IMD:

- Fog related weather forecast in winter.
- Weather forecast of the terminal area.
- Information related to wind including speed, temperature and direction.
- Information at the crucial time of zero visibility.
- Information about appropriate Runway Visibility Range (RVR).
- Information about ARFOR (Area Forecast/ Local Forecast used while climbing).
- Information about cloud visibility, temperature, dew point. etc.

Appropriateness of weather forecast provided by IMD during severe weather conditions as mentioned by the respondents were:

- Partially accurate to accurate (qualitative survey)
- In the past, the services were not always timely. However, it has improved significantly since IMD started using online services

Economic benefits of on-time weather information as per respondents were:

- Avoidance of flight cancellations, diversions and delays
- Cost savings for airline operators in terms of costs on fuel, passenger, and employee

Cost of not providing adequate information on time would be high for airlines as Rs 8 lakh on an average is spent for diversion of a single aircraft.

2.14.5 Issue 5: Current Modes of Dissemination of Information and Its Adequacy

The following modes are currently used to disseminate information:

- Internet: Each airline operator has a unique id and password to log in and access online information from IMD website
- Telephone
- Online briefing system from IMD website
- Immediate information in case of zero visibility and in emergency
- Hard copy of information, namely 'Met/Meteorological folder' containing complete information about wind speed, direction, temperature and weather at various destinations

Suggestions:

- Correct and timely information to airlines is of vital importance.
- Maybe we can think about an intermediate source such as call centres to disseminate information from IMD to airlines and to AAI.
- Airport-wise checklist should be planned by IMD to cross-check whether information is provided on time.
- Electronic version of Met folder.

2.14.6 Issue 6: What is the Usefulness of Weather Forecasts Information from IMD?

Weather forecast information is used for

- Flight planning
- Flight take-off
- Flight landing

Information is helpful

- To take quick and correct decisions for flight planning operations and its safe landing and takeoff

Feedback

- Pilots are satisfied at the international and big domestic airports about the weather information update every 30 minutes

Suggestion

- For small airports, IMD should have large number of data collection centres

2.14.7 Issue 7: Perception Surveys on Weather Information Received

IMD information is chargeable or non-chargeable?

- Respondents, as mentioned before, were not very much aware about the amount paid by AAI to IMD for meteorological services
- According to them, a partial amount from RNFC goes to IMD
- If runway has to be changed, then the information becomes chargeable to cover the cost. It has not happened so far.

Problems faced in receiving information from IMD

The quality of services to aviation sector provided by IMD has improved significantly after they have started providing services online. However, the users still face the following problems:

- Information not always on time particularly in severe weather conditions, for example, in case of fog in north India in winter
- In case of certain turbulences or in case of zero visibility, accurate information not provided for smaller airports
- Information on Runway Visibility Range (RVR) not always timely in the small airports
- Persistent problems related to Internet and telephone connection in small airports during severe weather

Suggestions to deliver accurate and fast weather information

Based on the interviews, we suggest the following need to be done:

- Duration of information dissemination should be minimised
- Latest information should be provided
- Maintenance of equipment should be done timely
- Small airports should be upgraded
- Latest technology and modern equipment like Meteo France Instruments (MFI), High Performance Computing System (HPCS), and Display Units at ATC towers and airlines area for weather forecast information to be provided in small airports
- Manpower should be improved both in terms of number and quality
- Use of latest technology based information dissemination to be introduced
- Widened source of information from Internet in addition to IMD website

In a nutshell, IMD should focus on the following three areas:

1. Equipment upgradation and maintenance
2. Communication system for fast and accurate dissemination of information
3. Electronic folder of meteorological services information design with latest update

2.14.8 Issue 8: Terms of Trade to Air-transportation Turned Adverse since 2004–05

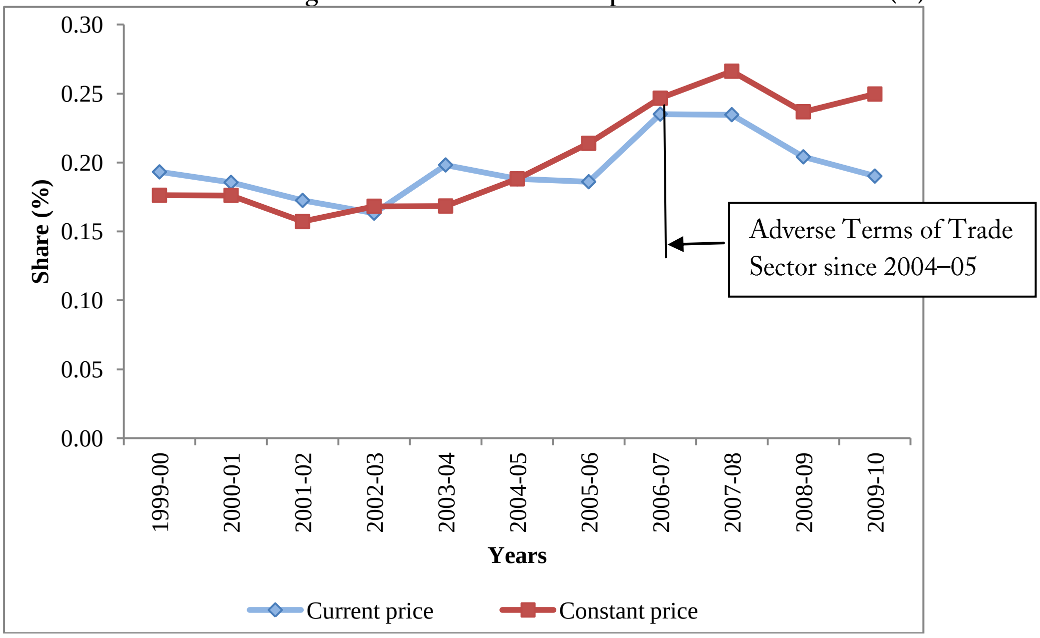
Terms of trade (tot) for air transport sector witnessed a sharp decline since 2004–05. Prior to that tot for airline transportation sector vis-à-vis non-air-transportation sector reveals this turn in setting of adverse tot in 2004–05. The share of air transport GDP to total GDP at constant (2004–05) prices were consistently above the share at current prices since 2004–05. For the period 1999–2000 through 2004–05, the share of GDP from air transport sector to total GDP at constant 2004–05 prices was consistently below the share at current prices. The difference in shares of GDP–air transport to total GDP at current and constant prices show that the tariffs set by airlines did not cover continued increase in fuel prices, or salaries since 2004–05. The difference in shares of GDP air transport to total transport at current and constant price reveal a similar story indicating that revenues received by airlines were sub-optimal (Table 2.8, and figures 2.3 and 2.4).

Table 2.8: Domestic Product from Transport (Rs crore)

	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	CAGR* for years 1999–2000 to 2009–10	CAGR for years 2005–06 to 2009–10
Current price													
Road transport	**68138**	**76836**	**83412**	**96203**	**112919**	**144097**	**163322**	**189286**	**214379**	**246029**	**276302**	**15.88%**	**14.04%**
Share of Total GDP (%)	3.81	3.99	3.98	4.25	4.45	4.85	4.82	4.79	4.68	4.66	4.50		
Share of Total Transport Sector (%)	90.47	90.31	90.94	92.17	90.61	92.30	92.32	91.58	91.47	92.07	92.62		
Water transport	**3728**	**4672**	**4694**	**4476**	**6667**	**6434**	**7285**	**8118**	**9246**	**10405**	**10356**	**11.15%**	**9.98%**
Share of Total GDP (%)	0.21	0.24	0.22	0.20	0.26	0.22	0.21	0.21	0.20	0.20	0.17		
Share of Total Transport Sector (%)	4.95	5.49	5.12	4.29	5.35	4.12	4.12	3.93	3.94	3.89	3.47		
Air transport	**3451**	**3572**	**3618**	**3691**	**5030**	**5590**	**6306**	**9290**	**10751**	**10779**	**11659**	**15.49%**	**14.77%**
Share of Total GDP (%)	0.19	0.19	0.17	0.16	0.20	0.19	0.19	0.24	0.23	0.20	0.19		
Share of Total Transport Sector (%)	4.58	4.20	3.94	3.54	4.04	3.58	3.56	4.49	4.59	4.03	3.91		
Constant price (2004–05)													
Road transport	**90818**	**97904**	**101603**	**112365**	**127182**	**144097**	**156725**	**170158**	**183974**	**196490**	**210402**	**9.33%**	**7.60%**
Share of Total GDP (%)	4.09	4.22	4.14	4.41	4.60	4.85	4.82	4.77	4.72	4.72	4.68		
Share of Total Transport Sector (%)	91.56	91.75	92.02	92.08	92.36	92.30	91.77	91.01	90.48	91.16	91.06		
Water transport	**4459**	**4718**	**4951**	**5383**	**5866**	**6434**	**7088**	**8015**	**8976**	**9193**	**9426**	**8.71%**	**7.33%**
Share of Total GDP (%)	0.20	0.20	0.20	0.21	0.21	0.22	0.22	0.22	0.23	0.22	0.21		
Share of Total Transport Sector (%)	4.50	4.42	4.48	4.41	4.26	4.12	4.15	4.29	4.41	4.27	4.08		
Air transport	**3916**	**4085**	**3856**	**4287**	**4657**	**5590**	**6960**	**8794**	**10378**	**9855**	**11218**	**13.15%**	**11.28%**
Share of Total GDP (%)	0.18	0.18	0.16	0.17	0.17	0.19	0.21	0.25	0.27	0.24	0.25		
Share of Total Transport Sector (%)	3.95	3.83	3.49	3.51	3.38	3.58	4.08	4.70	5.10	4.57	4.86		

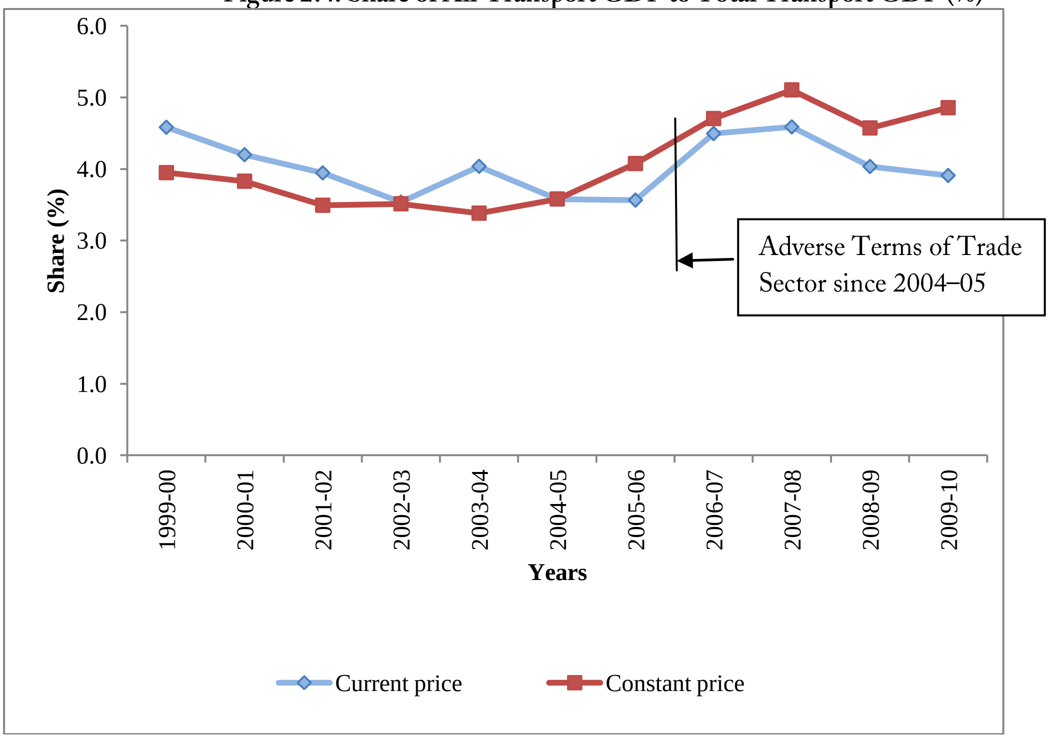
Source: Different Issues of Economic Surveys
**CAGR: Compound Annual Growth Rate*

Figure 2.3: Share of Air Transport GDP to Total GDP (%)



Source: Author's calculations NCAER, 2012

Figure 2.4: Share of Air Transport GDP to Total Transport GDP (%)



Source: Author's calculations NCAER, 2012

Suggestions to Improve Terms of Trade in Favour of GDP from Air Transport

One way to improve the terms of trade can be to decrease tot of aviation fuel. The Wholesale Price Index (WPI) of aviation turbine fuel (ATF) in India increased from 157 to 195 from 2007–08 to 2008–09. A study by ASCI on competition policies in the aviation sector estimated the fuel charges including surcharges and taxes at around 55 to 56 per cent of total operating expenses during December 2008 when the price of crude oil remained relatively high. The obvious result was a decrease in passenger traffic. However, the reverse happened internationally. In 2001, the international airlines lost $13 billion when the average fuel price was $30 per barrel. In 2010, the world airlines earned a profit of $15.8 billion when average oil price was approximately three times the price in 2011. International airlines are more affected by external events including a world recession which causes demand driven deceleration in revenues to airlines. May be a reduction in taxes and duties applicable to import of aviation fuel could have helped India in maintaining the level of its passenger traffic which is being tried out now. *May be a levy of very high RNFC by the AAI is also the culprit in ensuring an adverse tot for air transport GDP. This needs to be thoroughly examined by the regulator.*

2.14.9 Issue 9: Nodes (Airports) beyond a Threshold Distance with Sufficient Customer Push form the Integrated Network

More airports in terms of hubs mean higher number of NMSs providing more relevant information to the users in the aviation sector. In aviation industry in India, an initial hub and spoke network would be constructed to offer flights from one hub to one/multiple spoke cities.

If aviation industry in true sense is a networked industry in India, following the typical property of network analysis, more centres should benefit this sector. If more nodes are added, it provides greater business to users. The benefit would be indicated in terms of higher passenger and freight share in this mode of transportation. We would check whether it occurs or not. In other words, whether people choose to travel by air beyond a threshold distance when alternative modes of transport, say, road or rail are not available is to be checked. The threshold distance has been set at 500–600 km, an eight to ten hours journey by rail/road.

The six major hubs in terms of passenger share and freight share (2009–10) are Delhi, Mumbai, Kolkata, Chennai, Bengaluru, and Hyderabad. These six airports are considered as the main nodes in the network since these are the top six domestic airports considering passenger and cargo share. The geographical locations of these airports also play a crucial role.

Delhi tends to be the major airport in northern India; Kolkata in Eastern India; Mumbai in Western India; and Chennai and Bengaluru in Southern India while Hyderabad becomes the focal south central hub of India.

Delhi Airport, which had the largest passenger share of about 20.05 per cent in 2009–2010, is equipped with IIIA landing system which makes it operational even during dense foggy weather. The airport currently handles 48,792 domestic passengers and 22,779 international passengers daily. It has shown a tremendous growth of over 20 per cent in passengers share over the past ten years.

Mumbai Airport had the highest number of passengers handled per day till 2008–09. In 2009–10 it catered to 19.56 per cent of total passengers travelling in a day. Mumbai airport handles about 47,595 domestic passengers and 22,560 international passengers. The growth of its passenger share is also significant at 14 per cent over the last ten years.

Kolkata airport is the fourth largest airport in terms of number of passengers handled per day with about 3,196 international and 18,700 domestic passengers travelling each day. The passenger share of this airport has also grown at the rate of 19 per cent over the last ten years.

Chennai and Bengaluru airports had passenger shares of 7.50 per cent and 9.01 per cent, respectively, in 2009–10. While being the major airports in Southern India, they together catered to 15,320 international and 40,183 domestic passengers. Both Chennai and Bengaluru have maintained a growth of 19 per cent and 20 per cent, respectively, in passenger share over the last ten years.

Another significant airport to mention is the airport at Hyderabad which had a passenger share of 5.40 per cent, and catered to 13,143 domestic and 4,696 international passengers in 2009–10. In the case of its passenger share, it has maintained a significant growth rate of 21 per cent over the last ten years.

Table 2.9: Passenger and Cargo Share in Major Airports

Major airport	Passenger share (%)	Cargo share (%)
Delhi	20.05	23.76
Mumbai	19.56	26.08
Chennai	7.50	10.48
Kolkata	7.68	9.43
Bengaluru	9.01	9.98
Hyderabad	5.40	4.22
Others	36.20	20.27

Source: Author's calculations NCAER, 2012
Note: Figures are as on 2009–10

The top six airports are equipped with advanced technology and better meteorological equipment minimising customer dissatisfaction that may be caused due to delays and other technical difficulties that may arise in less developed airports.

Considering these major airports as the nodal points, other domestic airports located in their proximity are displayed below. Some of these are within the threshold distance while a few others are beyond it. We should note that the road distance in km is considered as the distance between the major hub and a smaller node. Seven airports from north and north-west (Jammu, Shimla, Srinagar, Agra, Lucknow, Vadodara, and Varanasi), three airports from south (Kozhikode, Thiruvananthapuram, and Kochi) and four airports from East (Patna, Agartala, Guwahati, and Imphal) are chosen for the analysis.

Table 2.10: Pattern of Network within and beyond Threshold Distance

Airport	Distance from main hub	Freight share	Passenger share	Within threshold distance or not
Jammu	Delhi	Decreased	Decreased	YES
Shimla	Delhi	No freight share	Constant	YES
Srinagar	Delhi	Decreased	Increased	NO
Agra	Delhi	Decreased	Decreased	YES
Lucknow	Delhi	Increased	Increased	YES
Vadodara	Delhi	Decreased	Decreased	YES
Varanasi	Delhi	Decreased	Decreased	YES
Thiruvananthapuram	Chennai	Decreased	Decreased	NO
Thiruvananthapuram	Bengaluru	Decreased	Decreased	NO
Kochi	Chennai	Increased	Increased	NO
Patna	Kolkata	Decreased	Decreased	YES
Agartala	Kolkata	Increased	Decreased	YES
Guwahati	Kolkata	Decreased	Decreased	NO
Imphal	Kolkata	Increased	Decreased	NO

Source: Author's calculations NCAER, 2012

Tourist destinations such as Agra and Shimla, lying within the threshold distance of Delhi, have displayed a slower rate of growth of passengers over the last decade. This is indicative of the fact that despite the large number of tourists travelling to these places, air transportation has declined. Clearly people must be preferring road or rail transportation, which also tends to be more cost effective and provides direct connectivity to the heart of the city.

Lucknow, being an exception, has displayed a rising growth of passengers handled over the past decade. This however, is attributable to the flights being diverted from Delhi airport due to bad weather conditions, mainly fog in winter season. Similar reasons suggest that an increase in passenger traffic to Jaipur could be due to its position as the alternate airport to Delhi.

Airports at Vadodara and Kozhikode, lying within the threshold distances from major airports, have displayed a decline in passenger share growth which has further lent credibility to our claim.

Similarly, airports such as Patna and Varanasi, lying within the threshold distance of Kolkata, also support our analysis. They have displayed a decline in the growth of passenger share.

Airports in the north-east, such as those located in Guwahati and Imphal, have also displayed a decline in the growth of passenger share, despite them lying outside the threshold distance of Kolkata. Moreover, the low demand for travelling to/from the east is the core reason for the decline in the growth of passenger share.

Implications for IMD

The aviation industry can be considered as a network industry following the aboveanalysis. However, the nodes within the threshold distance (500–600 km) do not get integrated into the network and the alternative mode of transportation could be more cost effective.

Therefore, having more airports does not necessarily have a value addition to the industry/NMSs unless these nodes have the demand push.

2.14.10 Issue 10: Role of Policy and Regional Planning for Meteorological Services

IMD should emphasise more on policy and planning for safer and technologically advanced forecasting system as Mexico focused intensely on new policies and planning after realising the potential growth of Mexican aviation sector.

Implications for IMD

IMD should examine the possibility of collaborating with countries that have advanced Met service forecasting systems.

2.14.11 Issue 11: Passenger Traffic Share over the Decade: Herfindahl Index Analysis

Passenger market concentration or market structure is often measured in two ways: N-firm concentration and Herfindahl indices. The N-firm concentration is calculated as the combined market share of the N largest airports in the country. Market share of airports is based on passengers and freight handled.

The Herfindahl Index, on the other hand, is the sum of the squared market shares of all the airports in the country. Market shares in this case are represented as proportions, that is, 15 per cent share will be written as 0.15. The Herfindahl Index ranges between 0 and 1. A more concentrated passenger traffic as in the case of a monopoly or a single airport will have an index closer to 1. And as airports increase and passenger traffic tends to get evenly distributed, this index value moves closer to 0. The concentration of passenger and freight traffic (both domestic and international) in the case of Indian airports is presented below.

Table 2.11: Concentration of Passenger and Freight Traffic Airports: Herfindahl Index

Year	Herfindahl Index					
	International			Domestic		
	2001–02	2005–06	2009–10	2001–02	2005–06	2009–10
Passenger share	0.211	0.184	0.150	0.113	0.122	0.105
Freight share	0.248	0.231	0.224	0.150	0.166	0.157

Source: Author's calculations NCAER, 2012

Over the period of ten years, the Herfindahl Index of the international sector has significantly declined in passenger share and marginally in freight share. We can infer that the addition of more international airports in the country have distributed the passenger share over new airports as well, indicating people's preferences in taking international flights from airports close to their home towns rather than major airports like Delhi or Mumbai. Hence addition of more international airports will benefit the industry.

On the other hand, the Herfindahl Index of the domestic sector passenger share has declined marginally, with freight share remaining constant. Hence, the addition of domestic airports in the country have not amended the market share of each airport indicating that an expansion in the domestic sector in terms of airports may not be the appropriate macro strategy for air transport sector and the Met services associated with air transport.

Implications for IMD

If civil aviation affects the macro strategy of integrating airports that provide hinterland connectivity to international passenger traffic then IMD should be prepared for such an eventuality.

2.14.12 Issue 12: Passenger / Cargo Market Share vis-à-vis Passenger / Cargo Market Growth Rates Analysis

Perhaps the most recognised of all portfolio frameworks is the one developed by the Boston Consulting Group. We tweak the framework for our analysis. The passenger / cargo market share is shown in the vertical axis with the growth rates of market shown in the horizontal axis. Market shares are divided into three hierarchies—high, medium and low—and growth-rate-wise rankings are confined to airports listed in the hierarchy.

Implications for IMD

The object is to identify airports (nodes) in the category low-share-low category. IMD can position the automatic weather stations in these low-share-low growth category airports. Analyses are succinctly shown below:

Business Hubs

Bengaluru, Chennai, Kochi, Hyderabad, Delhi and Mumbai can be conceived as hubs for international passengers as these airports have a high international passenger traffic share as well as a high passenger and cargo traffic growth. Kozhikode, on the other hand, caters to the needs of international passengers travelling to the Middle East for business purposes, which attributes to its high growth.

Table 2.12: Passenger Market Share and Passenger Market Growth – International

	International passenger market growth High	 Low
High international passenger share	Bengaluru Kochi Hyderabad	Chennai Delhi Mumbai
Medium international passenger share	Tiruchirapalli Kozhikode Ahmedabad	Thiruvananthapuram Kolkata Amritsar Goa
Low international passenger share	Coimbatore Guwahati	Jaipur Varanasi Lucknow Nagpur

Source: Author's calculations NCAER, 2012

Table 2.13: Passenger Market Share and Passenger Market Growth – Domestic

	Domestic passenger market growth High	Low
High domestic passenger share	Kolkata Delhi	Bengaluru Chennai Hyderabad Mumbai
Medium domestic passenger share	Jaipur Guwahati Pune Lucknow	Kochi Srinagar Coimbatore Ahmedabad Goa
Low domestic passenger share	Thoothukodi Shimla Rajamundry Chandigarh Bhubaneshwar Dehradun Tiruchirapally Raipur Ranchi Agatti Imphal Bagdogra Visakhapatnam Indore Dimapur Amritsar Patna Agra Portblair Kolhapur	Jabalpur Madurai Nagpur Aizwal Leh Agartala Jorhat Silchar Bhopal Bhuj Mangalore Tirupati Udaipur Thiruvananthapuram Aurangabad Dibrugarh Jammu Juhu Vadodara Varanasi Khajuraho Diu Porbander Rajkot Jodhpur Teju Bhavnagar Jamnagar Kozhikode Tejpur Gwalior

Source: Author's calculations NCAER, 2012

Mandi Towns

Domestically, Thoothukodi and Rajamundry, Mandi towns, have fueled air travel from and to these places. Indore, having a low passenger share but a high passenger growth rate, indicates its importance as an emerging business hub in Madhya Pradesh.

Emerging Business Hubs

Guwahati, on the other hand, displays a high passenger growth rate with a medium passenger share. Its high growth is attributable to the emerging businesses and educational centres there. Jaipur has long been known for its tourist attraction and thriving businesses. This has, therefore, accelerated passenger traffic to this city, categorising it as a high growing airport with medium passenger share. Similarly Goa and Srinagar have medium passenger traffic share due to these being tourist destinations. Pune and Lucknow have also become important business hubs of Maharashtra and Uttar Pradesh, respectively, leading to greater passenger traffic to these cities.

Based on such an analysis, IMD could recognise which airports would join the existing air traffic network. Since Met services are a derived demand, IMD needs to have an idea of how the future demand for air traffic would emerge across the country. The analysis is expected to provide insights for IMD.

Table 2.14: International Cargo Traffic Analysis

	International cargo market growth	
	High	Low
High international cargo share	Delhi Chennai	Mumbai Bengaluru
Medium international cargo share	Hyderabad Kochi Kozhikode	Kolkata Thiruvananthapuram
Low international cargo share	Ahmedabad Amritsar Tiruchirapalli	Guwahati Varanasi Jaipur Goa Nagpur Coimbatore Lucknow

Source: Author's calculations NCAER, 2012

Table 2.15: Domestic Cargo Traffic Analysis

	Domestic Cargo Market Growth High	Low
High domestic cargo share	Chennai Delhi Kolkata	Mumbai Bengaluru
Medium domestic cargo share	Pune Hyderabad	Kochi Ahmedabad
Low domestic cargo share	Bhopal Imphal Ranchi Jaipur Agartala Indore Amritsar Madurai Bhubaneshwar Lucknow Portblair Patna Bagdogra Leh	Visakhapatnam Nagpur Coimbatore Mangaluru Aurangabad Jammu Aizwal Juhu Bhuj Jodhpur Bhavnagar Tejpur Jabalpur Agra Dehradun Diu Gwalior Khajuraho Kolhapur Porbander Rajamundry Shimla Teju Thoothukodi Udaipur Thiruvananthapuram Goa Raipur Rajkot Guwahati Jamnagar Srinagar Dimapur Chandigarh Varanasi Dibrugarh Vadodara Jorhat Kozhikode Agatti Tiruchirapally Tirupati

Source: Author's calculations NCAER, 2012

IMD could consider providing only Automatic Weather Station in Low Domestic Cargo Market Growth and Low Domestic Cargo Share airports.

2.15 Concluding Remarks

- If RNFC charges remain at the current levels, IMD should be entitled to 6 per cent of these as meteorological services fee. If RNFC is brought down on the intervention of AERA, IMD could settle in for a levy of Rs 85 crore at 2011–12 prices.
- If AAI agrees to pay 6 per cent of RNFC towards Met charges, the remaining 94 per cent should be sufficient to earn a 12 per cent IRR on Gross Fixed Investments (Gross Block)
- The evidence based analysis suggests that it is not prudent to commercialise provision of Met services. IMD should continue to enjoy monopoly rights in provision of Met services.
- RNFC now levied as per technical norms may not be an appropriate levy per cost recovery principles and could be brought down significantly. AERA, the regulatory agency, could examine this afresh.

Technology Policy for Marine Water Desalination

Chapter 3
Marine Water Desalination

3.1 Introduction

3.1.1 Water: A "Special" Natural Resource

Water is a "special" natural resource. It is "special" because it is the only natural resource needed to sustain life (every individual needs at least 50 litres of water a day, just to sustain life). Besides this fundamental requirement water has commercial uses in the industry and agriculture segments.

In the global context, water is an abundant resource that covers three quarters of the earth's surface. However, only about 3 per cent of all water sources are potable. About 25 per cent of the worlds' population does not have access to satisfactory quality and/or quantity of freshwater and more than 80 countries face severe water problems. Worldwide drought and desertification are expected to sharpen the problem. Even countries that at present do not face water shortages may have to tackle the problem of fresh water scarcity in the near future. According to the *Worldwatch Institute*, more than two-thirds of the world's population may experience water shortage by 2025, thus affecting practically every country in the world, including the developed, unless they reduce demand and/or develop additional water sources.

3.1.2 India's Water Economy

India accounts for about 2 per cent of the world's land area and 4 per cent of fresh water while being home to 16 per cent of the global population. The current scenario of India's water economy is presented in Table 3.1.

At present, around 690 billion cubic metres (BCM) of surface water and 390 BCM of ground water is available in India. Of the total groundwater use, around 91 per cent is used for irrigation and the remaining 9 per cent for combined industrial and household consumption. If we look at both groundwater and surface water demand, more than 70 per cent of total water resource demand is for irrigation and only 6 per cent is for industry. Drinking water for citizens accounts for the remaining 17 per cent water demand.

Table 3.1: India's Water Economy

<table>
<tr><th rowspan="2">User sector</th><th colspan="2">Water resources available</th><th rowspan="2">Desalinated water</th><th colspan="2">Total water use (BCM)</th></tr>
<tr><th>Surface water</th><th>Ground water</th><th>2010</th><th>2025</th></tr>
<tr><td>Irrigation</td><td>NA</td><td>91%</td><td>Aquifers recharging</td><td>77% to 83%</td><td>73 %</td></tr>
<tr><td>Industries + Energy</td><td>NA</td><td rowspan="2">9%</td><td>• Power plants
• Paper
• Iron and Steel
• Dyes
• Chemical
• Leather</td><td>6.0%</td><td>8.5 %</td></tr>
<tr><td>Domestic</td><td>NA</td><td>• Islands
• Coastal cities
• Barge-mounted LTTD/coastal
• Hinterland</td><td>16.7%</td><td>18.5 %</td></tr>
<tr><td>Total (BCM)</td><td>690</td><td>396</td><td></td><td>600</td><td>950–1180</td></tr>
</table>

Source: National Commission for Integrated Water Resources Development Plan, Ministry of Water Resources, 1999, as cited in Centre for Science and Environment [CSE] (2004): "Total Water Management", Dr S. Prabhakar, Plant Superintendant, NDDP and AUGF, BARC Facilities, February 2012.

Total annual demand for water from all sectors in India is expected to increase from 600 BCM in 2010 to 1180 BCM by 2025. This would represent virtually the entire utilisable water resources in the country not being able to meet the required demand. While nearly two-thirds of the world's countries will be water-stressed by 2025, the problem is expected to be more acute in Asia, particularly India, which is likely to be water stressed by 2020. Therefore, given its scarcity, and also the projected water demand for the future, integrated water management is the need of the hour. Consequently we need to analyse both demand and supply side factors as below.

3.1.3. Demand and Supply Side Factors

Demand Side Factors Determining Water Consumption

- Improving water use efficiency through use of sprinkler irrigation system
- Minimising water discharge

Supply Side Factors Determining Water Augmentation

- Ground water recharge structures
- Rain water harvesting structures
- Upgradation of water supply systems to minimise losses in transportation of water
- Increasing waste water treatment capacity
- Desalination of sea water
- Aquifer recharge through desalinated water

3.1.4 Desalinated Sea-water: A Supply Side Solution

In India demand for desalinated water is growing across all sectors—household use for drinking water consumption, process need in different industries as well as irrigation purpose. Infrastructure too, is growing at a great pace. Therefore, the rate of water scarcity will only increase with time, requiring more investments in desalination and water reuse.

India is the largest user of ground water for irrigation. According to one estimate, the amount of drawn groundwater is estimated to be 210 BCM per year compared to 105 BCM in China and 100 BCM in US (Shankar et al. 2011). The problem is that this pattern of using the source is not sustainable. Around 80 per cent of the rural population relies on groundwater for meeting their drinking needs. In many areas groundwater is fast running out and river water is overexploited. Therefore, another strategy for water-stressed areas can be artificial groundwater recharge. Recharge can help move excess salts that accumulate in the root zone to deeper soil layers, or into the groundwater system. In many areas aquifers that supply drinking-water are being used faster than they naturally recharge. Moreover, in coastal areas, aquifers containing potable water can become contaminated with saline water if water is withdrawn faster than it can naturally be replaced. Aquifers can be recharged artificially with desalinated water, using either infiltration or injection. As shown in Table 3.1, demand of water for irrigation purpose can be solved to a considerable extent through aquifer recharging. At the same time, it can be a successful method to meet the domestic sector water demand in the hinterlands.

3.1.5 Industrial Sector Demand: Potential for Usage of Desalinated Water

Potential for usage of desalinated water for industry use is very high in Gujarat and Tamil Nadu. Gujarat, once considered a water-scarce state, has the highest desalinated water generation capacity at present in the country, mainly because of state government initiatives. Gujarat uses thermal desalination technology in many industries near the coastal areas. Similarly, in Tamil Nadu, the support of the state government has enabled it to have the second highest desalinated water capacity in the country, mostly based on RO technology, contributing 24 per cent to total desalinated water output in India.

Among the mega industries, three that use the maximum amount of water are power plants (boiler feed water) and iron and steel plants (process use). These industries mostly use thermal desalination technology to generate pure water. Among micro, small, and medium enterprises (MSMEs), dyes and chemicals and leather industries use large amounts of pure water for process use. These enterprises mostly use membrane-based RO technology for desalination.

3.1.6 World Wide Trends in the Cost of Desalination

The cost of desalination has reduced considerably across the globe as compared to that existed around 15 years back. In the last decade, desalination was considered as a solution for potable water needs only for those countries having cheap fuel. Now, desalination is extensively used even where it was unthinkable twenty years back, because of reduction in desalination cost. The cost reduction has a direct correlation with increase in desalination capacity and depends on the quality of the feed water available at the selected sites. Most desalination plants in the Arabian Gulf region are cogeneration type, producing both power and water. If fossil fuel prices have increased, use of nuclear or renewable energy may be cost effective for desalination. Moreover, if the cost of desalination decreases (as has been over the years) the gap between conventional water supply and desalinated water would narrow.

3.2 Technology Policy on Desalination

As discussed above, any technology policy encompassing the issues of energy and water must include comprehensive coverage of desalination. More energy intensive processes generally mean more carbon dioxide emissions which may not be a major concern vis-à-vis ecological effects that negatively impact the existing eco-system and the livelihood of fishermen, an important set of stake holders in the Indian context, as shown in computations elsewhere in this chapter.

3.2.1 Environmental and Ecological Factors in Shaping Technology Policy

Adoption of technologies for desalination can have adverse environmental and ecological side effects. For instance, adoption of certain technologies can cause considerable damage to ecology and environment in a number of ways including (i) the uncontrolled discharge of concentrated brine that can contaminate water aquifers and damage aquatic ecosystems. The brine discharge may also contain pre-treatment chemicals, corrosion materials, nuclear contaminants, etc.; (ii) desalination plants use the thermal energy from an attached power plant from the waste water discharge of the condenser unit. The electrical energy used in the process of desalination emits carbon dioxide, which results in environmental pollution. Generally the lesser the energy requirement by desalination technology, the lesser this indirect environmental impact is going to be; and (iii) desalination plants may cause noise pollution, gaseous emissions and chemical spills. As far as the harmfulness of discharged concentrate is concerned, total dissolved salts (TDS), temperature and specific weight (density) of the discharge are of critical importance as they result in damage to the aquatic environment. TDS discharge is directly proportional to the recovery ratio of the plant. The increased temperature can also harm the aquatic life. **The increased density results in the sinking of the discharge termed as desertification of seas causing harm to certain parts of the ecosystem.**

Von Medeazza explained the likely impact of desalination (energy and brine associated pollution) succinctly in EPW, March 2006, which is illustrated below.

"Under the present plan, the two major environmental impacts of RO process of desalination (energy and brine associated pollution) must also be considered carefully. What will be the long-term effect of such brine pollution on Chennai's coast? A close examination should be made of the discharge of around 100 MLD of brine that will take place at the Minjur site. Brine is an unavoidable by-product of desalination, most commonly discharged into the marine environment. The environmental implications of this highly concentrated salt solution (around 70,000 ppm) on local marine ecosystems have been debated for many years. However, it is now widely acknowledged that extensive brine discharge, as it constitutes a hypersaline layer that sinks towards the seabed due to its greater density, has the potential to heavily affect local marine biota. The United Nations Environment Programme (UNEP) recently stressed the gravity of the problem: 'marine desertification' has become evident with the desalination activity along the Gulf coastline. Furthermore, during pre- and post-treatment processes, a variety of chemical agents are added to enhance flocculation, prevent foaming or to avoid membrane deterioration. Resulting eutrophication, pH value variations, accumulation of heavy metals and disinfectants have pronounced effects on receiving waters."

3.2.2 Technology Choice – Methodology Outline

The choice of technology could be decided on the basis of the composite cost of providing one litre of desalinated water. The composite cost would be arrived at as the cumulative cost of the following:

i. Price per litre of desalinated water that would yield a 12 per cent IRR on investments in desalination plant, assumed as the base cost.
ii. Environmental cost per litre of desalinated water is arrived at on the basis of additional energy consumption per litre of desalinated water over the technology option with the least specific energy consumption. In the Indian context, 1 Mega Watt Hour (MWH) energy consumption is assumed to imply a tonne of carbon dioxide emission. If a process involves a reduction of specific energy consumption by 1 MWH, it is assumed to have earned one Certified Emission Reduction (CER).
iii. Ecological cost per litre of desalinated water is arrived at as the change in GDP per litre of desalinated water in the 'project catchment area' due to the introduction of a particular technology. The reduction/increase in final output in the project area is arrived at by evolving an Input–Output Table for the project catchment area and arriving at both direct and indirect effects of the introduction of technology from the Leontief-Inverse Table.

For instance, the introduction of LTTD technology in Kavaratti for supply of drinking water is an eco-friendly option vis-à-vis other technology options such as RO process based desalination. This technology option allows continuation of ornamental fishing activity. Thus LTTD technology adoption would not entail any ecological cost while others that affect the ecosystem would entail the ecological cost equivalent to the lost GDP per unit output.

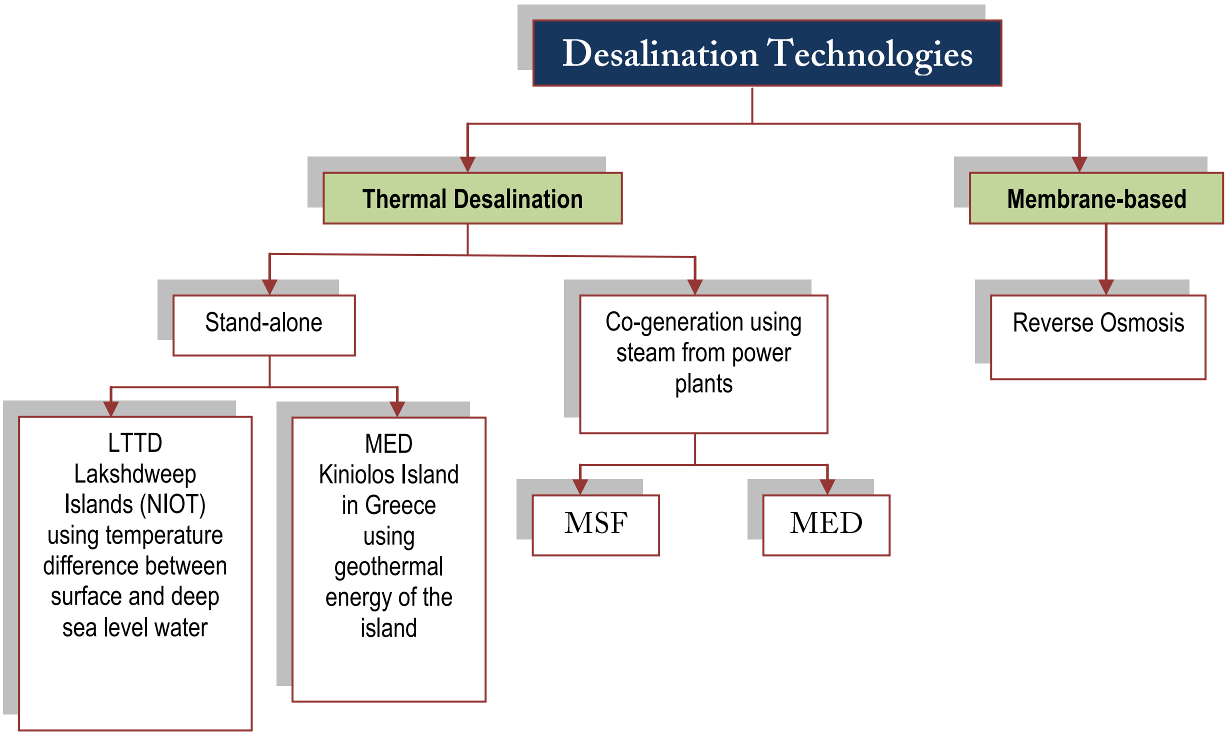
The concept is illustrated and computation of ecological cost per litre of desalinated water for RO technology adoption in Thoothukodi is explained, in detail elsewhere in this chapter.

The composite cost is arrived at as the sum of base cost/unit output, environmental cost/unit output and ecological cost/unit output.

3.2.3 Categories of Desalination Technologies

The commercial desalination technologies can be divided into two main categories: thermal distillation (MSF and MED) and membrane separation (RO). In addition, there are other commercial technologies adopted to a very less extent due to their small unit size such as vapour compression (VC), electro dialysis (ED) etc. which are not discussed here.

Figure 3.1: Desalination Technologies



Note:

- LTTD: Low Temperature Thermal Desalination
- MED: Multi Effect Distillation
- MSF: Multi Stage Flash Distillation
- Cogeneration: waste heat utilisation (power plants)

Source: NCAER, 2012

Thus the evolution of technology policy in the Indian context in choice of desalination technology would be as illustrated in Figure 3.1.

For instance, based on interviews with experts and field visits to desalination plants as part of the study, it was observed that LTTD is the best technology for islands because of many inter-connected factors. RO is not suitable for islands because of various reasons such as high brine discharge and the consequent disturbance in the eco-system affecting the livelihood of fishing households in the islands, corrosion of mechanical parts, and requirement of skilled labour. The reasons behind preference of LTTD are:

- An LTTD plant uses higher energy for its operation compared to the membrane-based RO technology. In spite of high energy usage, LTTD is the preferred technology for coral islands since it is eco-friendly. This is because it does not disturb the marine eco-system as there is no discharge of brine solution into the sea.
- LTTD does not necessitate storage of chemicals in islands unlike RO.
- LTTD process does not require skilled labour for its operation.
- LTTD is a stand-alone technology.

Given this broad context, the remainder of this chapter analyses issues such as:

- Desalination technologies
- Applications of LTTD process
- Base cost of desalination: Based on LTTD project in Lakshadweep Island and the proposed LTTD plant at Thoothukodi
- Environmental costs computation
- Ecological costs computation
- Composite cost computation
- Insights from primary field visit and structured interviews

3.2.4 Desalination Technologies

As was stated earlier, there are basically two types of conventional desalination processes: (1) Thermal desalination and (2) Sea-water RO. Under thermal desalination process, there are three different technologies: multi-stage flash desalination (MSF), multi-effect distillation (MED), and low temperature thermal desalination (LTTD). Each of these has been discussed below. MSF and MED are the major commercial thermal desalination technologies. Historically, thermal technologies have dominated the desalination market, particularly in the Middle East, where the low energy costs and large scale cogeneration plants have guaranteed the ascendance of thermal processes. These processes mimic the natural water cycle of evaporation and condensation and produce output water with very low salt concentration. Thermal desalination plants suffer, however, from formation of scales.

3.2.4.1 Multi-Stage Flash Desalination (MSF)

Multi-Stage Flash Desalination (MSF) produces pure water by boiling and then condensing saline water. In MSF, the saline feedwater first passes through a series of tubes. This essentially preheats the water before entering the brine heater. It is then heated in the brine heater using any given form of thermal energy. The heated water is then introduced into a vessel (called stage) where the ambient pressure is lower than the brine heater. This low pressure results in sudden boiling (flashing) of the saline water. The vapours, formed during the boiling, condense on the tubes carrying input saline water and the distillate is collected. Only a small percentage of the heated water is converted into steam depending upon the pressure maintained at each stage. The remaining water is then introduced to the next stage with an even lower pressure, and the process continues until the saline water (now brine) is cooled down and discharged. MSF plants may contain between 4 and 40 stages, but usually they comprise of 18 to 25 stages. The process explanation is taken from Buros and Cooley et al.

MSF has proven to be the most reliable thermal desalination technology as it has dominated the thermal desalination market during the 1980s and 1990s. MSF has 25 per cent worldwide capacity share. The overall trend is reducing due to the emergence of RO and MED (except in the Gulf region).

3.2.4.2 Multi-Effect Distillation (MED)

Multi-Effect Distillation (MED) takes place in a series of vessels or effects and uses the principle of evaporation and condensation at reduced ambient pressures. The plant design for MED vary in process details. Usually the feed water after being preheated in the final condenser is fed in equal proportions to the various vessels. The water is sprayed on the evaporator surface (tubes) after being heated by steam using the steam turbines of a power plant or boiler where the steam inside condenses as the water sprayed on the evaporators vaporises. The vapours (steam) from the first effect are used to heat the surfaces of the succeeding effects. The vapours produced to steam; in each effect, the remaining water forms the brine solution. In some designs, this water is fed to the input of the next effect. MED plants employ a separate vacuum system for maintaining different ambient pressures in different vessels. In upcoming applications of MED plants a vapour thermal compression cycle is added to the plant to reduce the number of effects and the surface area required.

3.2.4.3 Reverse Osmosis (RO)

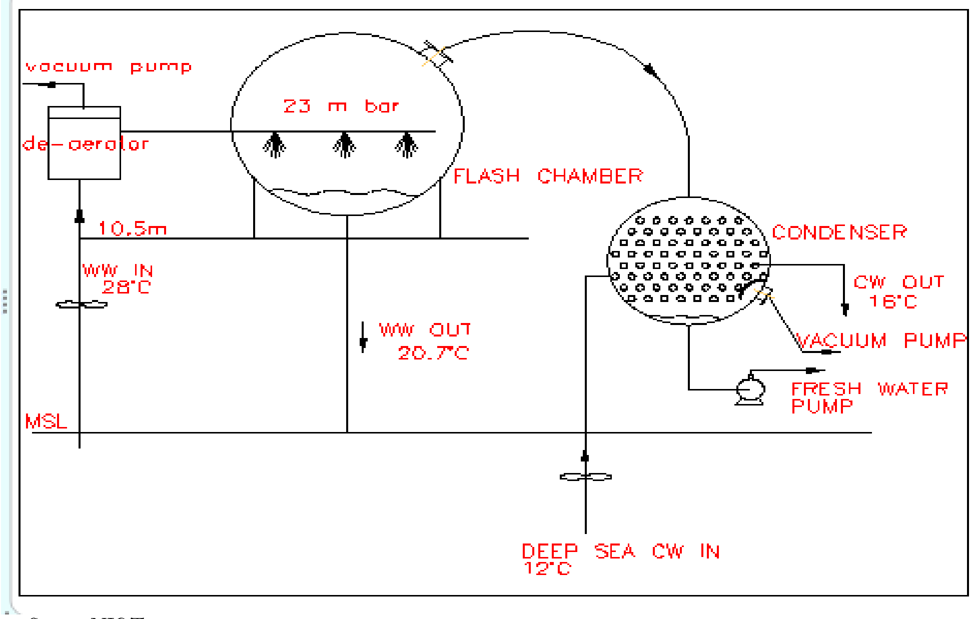
Membrane processes work by prohibiting or permitting the passage of certain salt ions. RO is the major commercial membrane process. RO is used to desalinate sea water. In RO process, the saline water is pumped into a closed vessel where it is pressurised against a membrane; pure water permeates through the membrane whereas the brine left behind is discharged. The brine discharge may have a concentration ranging from 20 to 70 per cent depending upon the salt content of the feedwater. An RO system is made up of a pre-treatment process, high-pressure pump, membrane assembly and post treatment process. Most modern reverse osmosis plants have an energy recovery system. The brine discharge is usually at a very high pressure whereas the fresh water is at a low pressure. The pressure energy in the brine is fed back to the feedwater using pressure exchangers. The usage of energy recovery systems and improved membranes has resulted in an overall reduction in the cost of RO-based desalination.

However, the disposal of the concentrated brine is the major drawback in the process, which affects the existing ecosystem. In the context of India, the technology that affects the existing ecosystem and the livelihood of fishermen cannot be an optimal one to adopt even if it is the most economical in terms of power consumption or cost. Ecological considerations that affect the livelihood of fishermen become important more than environmental consideration such as CO_2 emission norms.

3.2.4.4 NIOT's Low Temperature Thermal Desalination

Low Temperature Thermal Desalination (LTTD) is one process that uses the availability of a temperature gradient between two water bodies or flows to evaporate the warmer water at low pressure and condense the resultant vapour with colder water to obtain freshwater. While ocean, with its temperature variation across its depth, presents one such scenario of two water bodies, a coast-based thermal power plant discharging huge amounts of condenser reject water into the nearby ocean represents an alternative application. In the former case LTTD is a stand alone desalination plant (Lakshadweep case study) while in the latter, LTTD is a cogeneration thermal desalination unit. Sea water desalination is attaining increasing attention of present day policy makers, especially with the growing demands that urbanisation, population explosion, irregular rainfall, and ground water contamination place on the fragile natural resources. The main components of LTTD plant are the evaporation chamber, the condenser, pumps and pipelines to draw warm and cold water, and a vacuum pump to maintain the plant at sub-atmospheric pressures. A schematic diagram of the process is shown in Figure 3.2.

Figure 3.2: A Schematic of LTTD Process



Source: NIOT

The simplicity of LTTD process enables control of the quality of product water in order to provide either good quality drinking water or boiler grade water as demanded by the situation. One of the advantages of the process is that it can be implemented even with a low temperature gradient of about 8°C–10°C between the two water bodies. Even though flash distillation is a commonly used desalination process worldwide, especially in the Middle East, none of the established plants work with the temperature gradient as low as 8°C that exists in the LTTD plant in North Chennai Thermal Power Station (NCTPS).

3.5 Comparison of Desalination Technologies

A comparison of the LTTD process with RO process, MSF and MED in terms of principle of operation, environmental effects and ecological effects is briefly presented below.

Principles of operation: In RO, water at high pressure is made to pass through a porous membrane of size of 0.5–1.5 nm. The dissolved solids are left behind. However, LTTD works on the temperature gradient between two water bodies to evaporate the warmer water at low pressure and condense the resultant vapour with the colder water to obtain freshwater. In MSF, heated water flashes inside a low pressure chamber and the steam generated is condensed in a sequence of stages. MED is a distillation process where the evaporation of sea water is obtained by the application of heat delivered by compressed vapour inside horizontal tubes. Even though LTTD requires a higher initial investment, its operating and maintenance costs are the lowest compared to the other three technologies. The price per unit output that would yield 12 per cent IRR over the useful life is considered the base cost.

Environmental effects: Among the four technologies, RO consumes minimum electrical energy per unit output, followed by MSF, LTTD and MED. As a result, the adverse impact on the environment is much lower in RO as compared to LTTD and the other two technologies. Environmental effects are CO_2 emission from the extra specific electrical energy consumption as well as other effects associated with the chemical discharge and gaseous emissions.

Ecological effects: The most important ecological impact associated with desalination process arises due to brine discharge into the sea, which causes "sea desertification" and "imbalance to the marine eco-system". Brine discharge may also contain pre-treatment chemicals, corrosion materials, etc. In case of LTTD, sea desertification is negligible, while the same from an RO plant is very high. In case of MSF and MED, this phenomenon is low. RO has very high chemical discharge and causes eco-system disturbance, while the same is negligible in case of LTTD, MSF and MED. As a result, the adverse impact on fishermen involved in different activities such as ornamental fishing, crab-fattening and lobster culture, is minimal from an LTTD, MSF or MED plant vis-à-vis the RO alternative. The composite cost is arrived as the sum of base cost, environmental cost and ecological cost per unit output.

3.6 Applications of LTTD Process

NIOT has been working extensively in the field of LTTD and established plants of various capacities. NIOT started working with LTTD applications in 2004 and established various plants. Some of successful demonstrations of LTTD technology are mentioned below.

1. **Land based** plant in Kavaratti Island in Lakshadweep, with capacity of 100 m^3/day (2005)
2. **Power plant condenser reject water based** LTTD cogeneration plant at (a) NCTPS, with capacity of 150 m^3/day, Chennai (2009), (b) Thoothukodi (proposed)
3. **Barge Mounted Experimental Plant** off Chennai coast, with capacity of 1000 m^3/day (2007; currently dismantled after successful demonstration)

We would analyse Kavaratti Island LTTD plant as well as the proposed Thoothukodi plant in terms of the composite cost of base cost of process of desalination, environmental as well as ecological cost per unit output.

3.7 Island Based LTTD Plant at Kavaratti, Lakshadweep Islands

The desalination plants in islands designed under the concept of LTTD involves evaporating the surface sea water at about 22°C and condensing the resultant fresh vapour with deep sea cold water at 10–12°C, available at a depth of about 400 m below sea level in the oceans.

NIOT set up a land-based LTTD demonstration plant in Kavaratti with capacity of producing 1 lakh litre per day (lpd) of freshwater in May 2005. The sea bed bathymetry near the island was such that 350 m water depth was available at about 600 m from the shore. Temperature gradient of 15°C was utilised (temperature of surface water at 28°C, water at 350 m depth at 12°C). High Density Polyethylene (HDPE) pipes of 630 mm in diameter and 600 m in length were deployed to draw cold water from a depth of about 350 m. The sea water pumps inside the partitioned sump supply warm and cold water to the plant on the land. The plant has been running continuously since over four years, fulfilling the needs of the local community. The salinity of the freshwater produced was reduced from 35000 ppm of the seawater to 280 ppm whereas the permissible limit for drinking water is 500 ppm. Figure 3.3 gives a view of the Kavaratti Desalination Plant.

Figure 3.3: A View of the Kavaratti Desalination Plant

Source: NIOT

NIOT is currently in the process of establishing similar plants in three more islands of the region. The technological challenges in establishing island-based LTTD plants include design and installation of cold water pipeline from deep sea to near shore, design of marine infrastructure required for plant functioning and optimisation of process, using difference in ocean temperatures, which is a unique feature of NIOT's technology.

3.7.1 Application of LTTD in Islands: Base Cost Computations of LTTD Project in Lakshadweep Island

The costing involved in development and implementation of desalination technology for islands is presented in this section on the basis of an LTTD plant installed in Kavaratti, Lakshadweep[1]. The total cost of producing desalinated water consists of two broad categories of expenditure: (i) capital expenditure and (ii) operating expenditure.

Capital expenditure broadly consists of the following elements:

i) Land

[1] Source: "Costing of desalinated water from sea using low temperature thermal desalination technology in islands (Lakshadweep)", August 2010, Vinod K. Agarwal and Co., Chartered Accountants, New Delhi.

ii) Civil structure
iii) Plant and machinery
iv) Deep sea pipe lines
v) Technology and project implementation cost

Operating expenditure consists of running and maintenance of the plants under the following broad heads:
i) Personnel cost
ii) Electricity expense
iii) administrative expenses

The following specifications / assumptions have been followed while estimating the costing for desalination:

- Total project cost has been worked out for the capacity of 100,000 (100 m^3) lpd per day.
- The total life of the project has been estimated at 25 years.
- Certain components of the plants such as pumps and piping have the estimated productive life of ten years.
- A fee of 15 per cent has been allocated as cost of the project for design and support services to be provided by NIOT.
- Another fees of 15 per cent has been allocated for the project implementation by NIOT or another agency.
- The cost of capital employed has been considered at 12 per cent being the prime lending bank rate. This is also the social discount rate adopted by ADB / World Bank and Planning Commission for assessing public sector investments.

The total project cost and its breakup is presented in Table 3.2.

Table 3.2: Total Project Cost

Particulars	Amount (Rs lakh)	Total Amount (Rs lakh)
Land, Building, Plant, and Machineries		
Land	45.1	
SUMP	112.7	
Bridges	341.7	
Plant civil cost/skeleton	208.17	
Cold water pipe	216.13	
Plant and machineries	263.64	**1,187.44**
Intangibles and other contingencies		
Island transportation cost	44.4	
Design and support services by NIOT	184.78	
Project implementation fees	184.78	
Contingencies	123.18	
Insurance cost during project construction	12.32	505.06
Interest capitalised for construction period (IDC) not considered in DCF analysis		226.74
Project cost		**1,963.64**
Working capital requirement		**14.81**
Project cost including working capital requirement		**1,978.45**

Source: NIOT

Table 3.3 presents the breakup of yearly running and maintenance expenses.

Table 3.3: Yearly Running and Maintenance Expenses

Sl No.	Particulars	Amount (Rs lakh)
	Operating expenses	
1	Personnel expenses	18.35
2	Electricity expenses	21.93
3	Repair and maintenance expenses	6.55
4	Administrative overheads	12.42
	Total operating cost	**59.25**
	Monthly operating cost	**4.94**

Source: NIOT

3.7.2 Cost of Desalinated Water per Litre

Based on the project cost, operating and financial expenses, the estimated price of desalinated water from the island project to yield 12 per cent IRR has been worked out (Table 3.4).

Thus we can conclude that the price per litre of desalinated water is 74 paise if the project is expected to yield a 12 per cent economic IRR.

Table 3.4: Base Cost Computations – Price per Litre to Yield 12% IRR

Year	Capital cost excluding IDC	Operating cost salaries and wages	Operating cost electricity	Repair and maintenance cost	Travel, insurance and rent	Water output in lakh litres
1	1389.52					
2	362.19	18.35	21.93	6.55	12.42	182.5
3		18.35	21.93	6.55	12.42	365
4		18.35	21.93	6.55	12.42	365
5		18.35	21.93	6.55	12.42	365
6		18.35	21.93	6.55	12.42	365
7		18.35	21.93	6.55	12.42	365
8		18.35	21.93	6.55	12.42	365
9		18.35	21.93	6.55	12.42	365
10		18.35	21.93	6.55	12.42	365
11		18.35	21.93	6.55	12.42	365
12		18.35	21.93	6.55	12.42	365
13		18.35	21.93	6.55	12.42	365
14		18.35	21.93	6.55	12.42	365
15		18.35	21.93	6.55	12.42	365
16		18.35	21.93	6.55	12.42	365
17		18.35	21.93	6.55	12.42	365
18		18.35	21.93	6.55	12.42	365
19		18.35	21.93	6.55	12.42	365
20		18.35	21.93	6.55	12.42	365
21		18.35	21.93	6.55	12.42	365
22		18.35	21.93	6.55	12.42	365
23		18.35	21.93	6.55	12.42	365
24		18.35	21.93	6.55	12.42	365
25		18.35	21.93	6.55	12.42	365
26	-14.81	18.35	21.93	6.55	12.42	365
	Rs 1,518.84	Rs 143.92	Rs 172.00	Rs 51.37	Rs 97.41	2699.80
	Rs 0.563	Rs 0.053	Rs 0.064	Rs 0.019	Rs 0.036	Rs 0.735

Source: Author's calculations NCAER, 2012

3.7.3 Environmental Cost per Litre of Desalinated Water in Kavaratti Island, Lakshadweep

The LTTD plant set up in Kavaratti Island consumes around 10 KWH/cubic metre of power. RO process plants in India claim that they have achieved a specific electrical energy consumption of 4.5–5 KWH/cubic metre.

One unit of Certified Emission Reduction (1 ton of carbon-di-oxide emission) per CDM Executive Board = 1MWH under Indian conditions

Thus the LTTD plant which consumes additional 5.5 KWH/cubic metre of desalinated water entails an environmental cost computed as under:

Additional energy consumption = 5.5 KWH/cubic metre

or 5.5 KWH/1000 litres

Since 1 CER (1 MWH) is traded at around 6 Euros

We have the environmental cost as

= Rs 5.5/1000 * 1/1000 * 6 * 69.6

(1 MWH = 1000 KWH and 1 Euro = Rs 69.6)

= 5.5/1000 * 6/1000 * 69.6 * 100 paise

= 5.5 * 6 * 69.6/10,000 paise

= 0.23 paise

Thus the adverse environmental cost implications of adopting LTTD works out to merely 0.23 paise per litre

3.7.4 Ecological Cost per Litre of Desalinated Water in Kavaratti Island, Lakshadweep

Ecological costs due to adoption of LTTD plant is nil as the existing ecosystem will be preserved even after the introduction of LTTD desalination technology in Kavaratti Island. The additional GDP in the project catchment area resulting out of installation of LTTD plant and ornamental fishing activity in Lakshadweep has been dealt with in detail in Chapter 6. The 'additional' GDP which would be lost if the ecosystem is disturbed needs to be factored in an analysis of composite cost for other technology options.

Table 3.5: Price per Litre of LTTD Water that Would Yield 12 per cent Economic IRR

Particulars	Amounts (Rs)
Price per litre of LTTD water that would yield 12 per cent economic IRR	0.75
Impact on ecology	Negligible, hence the interests of fishermen—major stakeholders in the coral islands—are protected
Environmental Impact	Higher energy requirement for operation of the plants means there is an environmental impact. This works out to 0.23 paise per litre.

Source: Author's calculations NCAER, 2012

3.8 NIOT's LTTD Unit as a Cogeneration Plant in Power Plants

3.8.1 North Chennai Thermal Power Station

It can be seen from LTTD plants that a temperature difference and adequate vacuum levels should be sufficient for generation of freshwater. One aspect of LTTD is that it transfers the available heat from warmer water to colder water while generating freshwater from the warm water. This aspect could, therefore, be aptly used in thermal power plants resulting in the double benefits of cooling the reject water from condenser and generating freshwater. A small temperature gradient of about 8°C–10°C, as is the case with most power plants, would be sufficient to utilise the concept. With the idea of demonstrating application of an LTTD plant in a coast-based thermal power plant, where the co-existence of warm power plant condenser rejected water and the nearby surface sea water with a gradient of about 8°C–10°C, NIOT set up the LTTD plant of North Chennai Thermal Power Station (NCTPS) and is in the process of setting up LTTD cogeneration unit in Thoothukodi.

3.8.2 Thoothukodi Thermal Power Station

Thoothukodi Thermal Power Station (TTPS) is situated near the new port of Thoothukodi on the sea shore of Bay of Bengal in Tamil Nadu and spread over an area of 160 ha. The units are all coal based. Coal is transported by sea through ships from Haldia, Paradeep, and Vizag ports to TTPS. Generation and plant load factor (PLF) for the year 2010–11 was 7113.696 MU and 77.33 per cent, respectively. TTPS has a total installed capacity of 1050 MW comprising five units of 210 MW each. Figure 3.4 shows the TTPS plant.

Figure 3.4: Thoothukodi Thermal Power Station

Source: NIOT

Thoothukodi city is in a water shadow area and facing severe water shortages and the water demand is heavily increasing. The plant requires about 1.5 MLD DM water with quality less than 1 ppm and 4 MLD of 100 to 200 ppm, in addition to domestic water for township and plant. The water requirement for the plant is currently met from river sources which is scarce in summer. Also other potential power stations are explored for implementation of future plants. The second unit of TTPS and a few private power plants are also getting commissioned. In order to meet the demand for clear desalinated water, NIOT has proposed a desalination plant in TTPS. LTTD has proposed considering the possibility of producing high quality water utilising the condenser discharge.

3.8.3 Application of LTTD in Mainland (Power Plant): Cost Based on LTTD Project in Thoothukodi, Tamil Nadu

Based on the project cost and operating and financial expenses, the estimated price of desalinated water per litre from the project in Thoothukodi to yield 12 per cent IRR has been given in Table 3.6.

Table 3.6: Base Cost of a 2 MLD Plant in Thoothukodi (Rs lakh)

Year	Capital cost excluding IDC	Operating cost salaries and wages	Operating cost electricity	Repair and maintenance cost	Travel, insurance and rent	Water output in lakh litres
1	2541.6					
2	635.4	46	241	27	34	3650
3		46	241	27	34	7300
4		46	241	27	34	7300
5		46	241	27	34	7300
6		46	241	27	34	7300
7		46	241	27	34	7300
8		46	241	27	34	7300
9		46	241	27	34	7300
10		46	241	27	34	7300
11		46	241	27	34	7300
12		46	241	27	34	7300
13		46	241	27	34	7300
14		46	241	27	34	7300
15		46	241	27	34	7300
16		46	241	27	34	7300
17		46	241	27	34	7300
18		46	241	27	34	7300
19		46	241	27	34	7300
20		46	241	27	34	7300
21		46	241	27	34	7300
22		46	241	27	34	7300
23		46	241	27	34	7300
24		46	241	27	34	7300
25		46	241	27	34	7300
26		46	241	27	34	7300
	Rs 2,775.82	Rs 360.78	Rs 1,890.20	Rs 211.76	Rs 266.67	Rs 53995.99
	Rs 0.051	Rs 0.007	Rs 0.035	Rs 0.004	Rs 0.005	Rs 0.102
Price to be recovered per litre to yield 12 per cent IRR = 10 paise						

Source: Author's calculations NCAER, 2012

3.8.4 Ecological Cost of Adopting RO Technology in Thoothukodi

Possible impact of the choice of RO technology for desalination on the economy of Thoothukodi district, as a whole has been analysed in the next sub-section.

3.8.4.1 Gross District Domestic Product

The gross district domestic product (GDDP) for Thoothukodi district has been estimated for the year 2009–10, using the available official data on the GDDP for the year 2008–09 and the gross state domestic product (GSDP) of Tamil Nadu for the years 2008–09 and 2009–10, as available from the Directorate of Economics and Statistics, Tamil Nadu.

These estimates are presented in Table 3.7.

Table 3.7: Estimates of GDDP for Thoothukodi District, 2009–10

	Industry	GDDP, 2009–10 (Rs lakh)
1	Agriculture and allied activities	139570
2	Forestry and logging	8553
3	Fishing	40596
4	Mining and quarrying	16105
5	Manufacturing	219702
6	Electricity, gas and water supply	5207
7	Construction	106477
8	Trade, hotels and restaurants	290072
9	Railways	2592
10	Transport by other means	200397
11	Storage	1177
12	Communication	24988
13	Banking and insurance	76551
14	Real estate, ownership of dwelling and business services	109460
15	Public administration	55285
16	Other services	150246
Gross District Domestic Product		1446978

Source: NCAER, 2012

3.8.4.2 Input–Output Tables

In order to assess the linkages between industries and to facilitate impact analysis of induced final demand, input–output (I–O) table for 2009–10 has been constructed for Thoothukodi district, based on the above GDDP estimates and the I–O coefficients available from the all-India I–O transaction tables compiled by CSO. Compilation of I–O table requires preparation of supply and use tables of domestic output of Thoothukodi district.

The supply and use tables and I–O table for Thoothukodi district are presented in Table 3.8.

Table 3.8: Supply Table of Domestic Output of Thoothukodi District, 2009–10 at Factor Cost (Rs lakh)

Commodity X Industry		1. Agriculture, livestock and forestry	2. Fishing	3. Mining, manufacturing, electricity, construction	4. Trade, hotels and restaurants	5. All other services	Output of commodities at factor cost	Trade and transport margins	Net indirect taxes	Output of commodities at market prices
1	Agriculture, livestock and forestry	193135	0	38545	0	0	231680	130007	-17752	343935
2	Fishing	0	47367	0	0	0	47367	36590	-734	83224
3	Mining, manufacturing, electricity, construction	1921	0	1411532	0	0	1413453	464233	97942	1975628
4	Trade, hotels and restaurants	202	0	16177	394466	0	410845	-336162	1794	76476
5	All other services	0	0	180	0	1059574	1059754	-294669	15528	780613
	Output of industries at factor cost	195258	47367	1466434	394466	1059574	3163099	0	96777	3259877

Source: NCAER, 2012

Table 3.9: Use Table of Thoothukodi District, 2009–10 at Market Prices (Rs lakh)

Commodity X Industry		1. Agriculture, livestock and forestry	2. Fishing	3. Mining, manufacturing, electricity, construction	4. Trade, hotels and restaurants	5. All other services	Inter-industry use of commodities	Final demand of commodities	Use of commodities at market prices
1	Agriculture, livestock and forestry	29645	0	141962	39207	45369	256183	87751	343935
2	Fishing	0	1448	828	58	0	2334	80890	83224
3	Mining, manufacturing, electricity, construction	14669	5224	898250	30123	272872	1221139	754490	1975628
4	Trade, hotels and restaurants	185	0	344	6024	53816	60369	16107	76476
5	All other services	2636	100	77559	28980	66822	176096	604517	780613
	Intermediate consumption at market prices	47135	6771	1118943	104394	438878	1716121	1543755	3259877
	Gross value added at factor cost	148123	40596	347491	290072	620696	1446978		
	Output of industries at factor cost	195258	47367	1466434	394466	1059574	3163099		

Source: NCAER, 2012

Table 3.10: I–O Table for Thoothukodi District, 2009–10 (Rs lakh)

Commodity X Commodity		1. Agriculture, livestock and forestry	2. Fishing	3. Mining, manufacturing, electricity, construction	4. Trade, hotels and restaurants	5. All other services	Inter-industry use	Final demand	Output at factor cost
1	Agriculture, livestock and forestry	22266	0	92244	27486	30573	172569	59111	231680
2	Fishing	12	824	454	38	0	1328	46039	47367
3	Mining, manufacturing, electricity, construction	27273	3738	618692	28652	195304	873657	539796	1413453
4	Trade, hotels and restaurants	11578	989	135795	19194	96718	264274	146571	410845
5	All other services	14459	956	191142	40854	103294	350706	709049	1059754
Gross input at factor cost		75588	6507	1038326	116225	425889	1662534	1500565	3163099
Net indirect taxes		446	265	39189	561	13126	53587	43191	96777
Gross input at market prices		76034	6771	1077515	116786	439015	1716121	1543755	3259877
Gross value added at factor cost		155646	40596	335939	294059	620739	1446978		
Gross output at factor cost		231680	47367	1413453	410845	1059754	3163099		

Source: NCAER, 2012

Table 3.11: Leontief Inverse for Thoothukodi District, 2009–10

		1	2	3	4	5
1	Agriculture, livestock and forestry	1.13951	0.01738	0.16900	0.10080	0.08113
2	Fishing	0.00017	1.01776	0.00067	0.00018	0.00016
3	Mining, manufacturing, electricity, construction	0.29531	0.16996	1.95159	0.20826	0.42900
4	Trade, hotels and restaurants	0.10236	0.04554	0.23718	1.09044	0.16197
5	All other services	0.13432	0.05445	0.33025	0.15832	1.19574
Output multipliers		1.67167	1.30510	2.68869	1.55801	1.86799

Source: NCAER, 2012

3.8.5 Activities for Which Impact Analysis Has Been Carried Out

Fishing

The total value of output of fishing activity in Thoothukodi district for the year 2009–10 at factor cost has been estimated at Rs 473.67 crore. However, at market prices, the value of output of fishing is Rs 832.24 crore. The difference between the market prices and factor cost of fish output is accounted by trade and transport (Rs 365.90 crore) and net indirect taxes (- Rs 7.34 crore).

According to the information provided, if RO technology, which includes the consequent discharge of brine, is used, the fish catch would decrease by about 30 per cent. This implies that there would be loss of Rs 142.10 crore (30 per cent of Rs 473.67 crore) in fish output at factor cost. Consequently at market prices, the loss would be Rs 109.77 crore in trade and transport services (30 per cent of Rs 365.90 crore; Rs 58.50 crore in trade activity and Rs 51.28 crore in transport activity). It is assessed that these losses will be in the final consumption of households and exports, thus the entire loss will be in final demand.

3.9 Impact on the Thoothukodi District Economy if RO Technology is Adopted

The loss on account of adopting RO technology in Thoothukodi has been assessed at Rs 142.10 crore in fish output, Rs 58.50 crore in trade activity and Rs 51.28 crore in transport activity. This is the direct impact on the economy of Thoothukodi district and is purely on account of brine discharge following the adoption of RO technology. However, decrease in output of the district in fishing, trade and transportation, will also indirectly affect other industries due to the inter-industry linkages in the economy.

For estimating the indirect impact, the static Leontief model (based on Leontief inverse: Table 3.11) is used. The estimated direct and indirect impacts on account of RO technology in Thoothukodi are shown in Table 3.12.

Table 3.12: Estimates of fall in Output in Thoothukodi District Due to Adoption of RO Technology (Rs lakh)

		Present estimates		Loss in output		% decrease	
		Final demand	Gross output	Final demand	Gross output	Direct effect	Direct and indirect effects
1	Agriculture, livestock and forestry	59111	231680	0	-1253	0.0	-0.5
2	Fishing	46039	47367	-14210	-14464	-30.0	-30.5
3	Mining, manufacturing, electricity, construction	539796	1413453	0	-5833	0.0	-0.4
4	Trade, hotels and restaurants	146571	410845	-5850	-7856	-1.4	-1.9
5	All other services	709049	1059754	-5128	-7831	-0.5	-0.7
Total at factor cost		1500565	3163099	-25187	-37237	-0.8	-1.2

Source: NCAER, 2012

For Thoothukodi district as a whole, the fall in output of the district will be 1.2 per cent if direct and indirect effects are taken into account as a result of brine discharge if RO technology is introduced in Thoothukodi. In absolute terms, the direct loss will be Rs 251.87 crore and indirect loss will be another Rs 120.50 crore, bringing the total loss to Rs 372.37 crore.

The total loss in output in Thoothukodi would be Rs 372 crore, if the traditional crafts' catch are affected due to the desertification of sea. Since traditional crafts contribute to 30 per cent of overall catch, a reduction of catch by 30 per cent maximum entails a staggering ecological cost, if the existing ecosystem is disturbed due to adoption of RO in Thoothukodi power plants; even a 10 per cent reduction in traditional crafts' catch can entail a staggering ecological cost per litre as shown below:

The loss in output translates to GDDP loss of Rs 316 crore. If the district power plants set up around 20 million lpd plants to cater to power plants as well as to meet the drinking water requirements for the townships, the ecological cost per litre works out to
Rs $316 * 10^7/20 * 10^6 * 365$

Rs 316/730

Rs 0.43

or 43 paise per litre.

The ecological cost of 14 paise per litre is enormous even if the catch is affected by a very marginal 10 per cent.

The 2 million lpd LTTD plant in Thoothukodi is expected to consume around 6 KWH per cubic metre power vis-à-vis RO's specific consumption rate of 4.5 KWH/cubic metre. This would translate into a very negligible environmental cost of around 0.05 to 0.06 paise per litre. Details are presented in Table 3.13.

Table 3.13: Cost of LTTD vs RO Plant in Thoothukodi

Particulars	Amount (paise per litre) for LTTD	Amount (paise per litre) for RO process
Price per litre to yield 12 per cent IRR on Thoothukodi LTTD plant investments	10	Not available
Environmental cost	0.05	0
Ecological cost	0	43 paise, if 30 per cent catch is affected; 14 paise, if 10 per cent catch is affected

Source: NCAER, 2012

In the case of Thoothukodi power projects, adoption of RO process for desalination would entail a huge ecological cost (ranging from 140% to 430% of basic processing cost) affecting the livelihood of traditional fishermen. It could range from 14 to 43 paise per litre. The LTTD emerges as the best alternative due to the eco-friendly nature of the technology.

3.10 Field Survey Results

3.10.1 Insights from Primary Field Visit: LTTD Plant in Kavaratti Island, Lakshadweep

Since desalination using LTTD technology seems to be ideal for the islands based on discussion with experts and literature search, we decided to conduct a primary field survey covering the LTTD plants being installed by NIOT in the context of Kavaratti Island, Lakshadweep. Even though LTTD uses higher energy, it does not adversely affect the marine eco-system and is maintenance-free unlike any RO based system. The simplicity of the LTTD process also enables to control the quality of product water in order to provide either good quality drinking water or boiler make-up water as the situation warrants.

The prime objective of the study was to assess the perception of households in this island regarding benefits of extracting desalinated water from the LTTD plant. It also focused on the socio-economic impact assessment of desalination technology in the Kavaratti Island in Lakshadweep.

3.10.1.1 Primary Field Survey: Coverage

The survey was carried out in Kavaratti Island in Lakshadweep during April 2012, using both quantitative and qualitative approaches. The quantitative survey was conducted by using semi-structured questionnaires among the household population (chief wage earner in the household). The qualitative component included in-depth interviews (IDIs) with officials at the plant site and in-charge of the desalination plant.

For the quantitative survey, the total sample size covered was 60. So 60 chief wage-earners from different households were interviewed. On the other hand, for the qualitative component, 3 IDIs were carried out with the officials in charge of desalination plant.

3.10.1.2 Demographic and Socio-economic Profile of Study Population

This section presents the demographic and socio-economic profile of the study population.

A. Age distribution

More than one third (35%) of the study population is in the age group of 31–40 years followed by 30 per cent of the individuals being in the age group of 51–60 years. The mean age of the study population is 44 years.

B. Educational attainment

The highest level of education attained by more than one fourth (30%) of the study population is found to be middle school. This is followed by one fourth (25%) of the study population who have completed only primary level of education. Another 20 per cent is observed to have attained higher secondary and above level of education. Illiterate population is found to be almost negligible.

C. Occupation

A little less than half (42%) of the study population reported that they are working as labourers. Less than one-tenth each of the surveyed population reported to be working as fisherman (8%) and housewife (7%) as the main occupation.

D. Family income

More than one-third (37%) of the study population reported that their monthly family income is in the range of Rs 10,000 to Rs 20000. This is followed by 17per cent population reporting family income in the range of Rs 20,000 to Rs 30,000. Another 17per cent is found to be earning between Rs 5,000 to Rs 10,000 per month. The average monthly family income for the entire surveyed population is found to be is Rs 27,220.

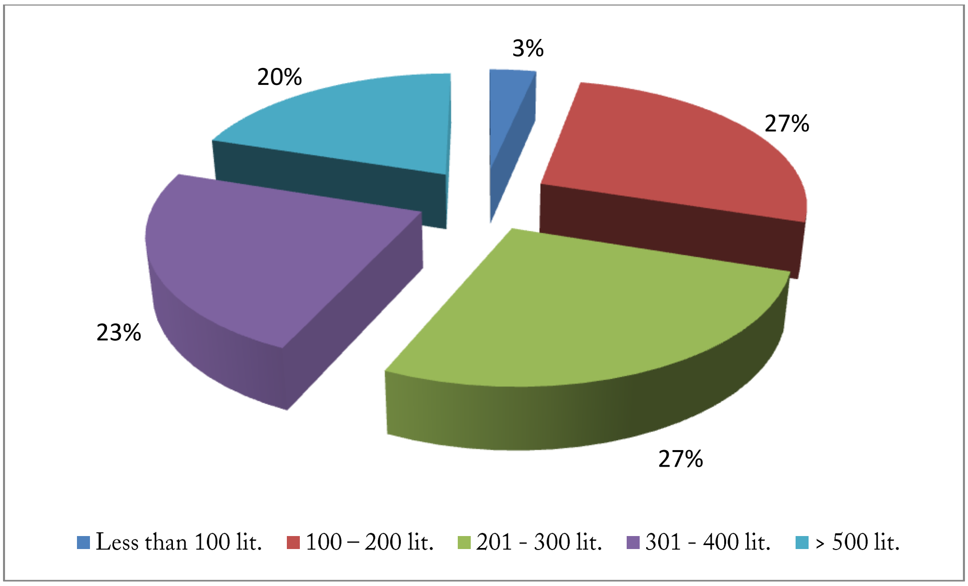
E. Fish exported and domestically consumed
Most of the study population (95%) reported no awareness of the share of fish exported. About 5 per cent of the study population reported that 10 per cent of the fish are exported. Most (95%) of the study population reported 100 per cent fish are domestically consumed. About 5 per cent of the study population reported that 90 per cent of the fish are domestically consumed.

3.10.1.3 Households' Water Consumption
This section presents water utilisation and consumption in the surveyed households in Kavaratti Island.

A. Total water utilisation per day per family

The study population was asked about the utilisation of water within their families per day. More than one-fourth (27%) of the study population reported that the utilisation is somewhat in the range of 100–200 litres. Another one-fourth reported that the utilisation is around 201–300 litres. The average water utilised per day within a family is found to be 320 litres per day. Figure 3.5 presents the water utilisation in the surveyed households.

Figure 3.5: Utilisation of Water per Family per Day, Kavaratti Island, Lakshadweep



Source: Primary Field Survey, NCAER, 2012 (April)

B. Water consumed for separate household activities

The survey also enquired about consumption of water for separately for different household activities such as drinking, cooking, bathing, toilet and MSC, cattle drinking and agriculture/horticulture. It was also asked whether they have to pay any money to the municipality for processed / treated water. All reported that they do not have to pay any money to the municipality for processed / treated water.

One-fifth of the study population reported consumption of 10 lpd on an average for drinking purpose, followed by 18 per cent consuming 20 lpd. Another 15 per cent households reported consumption of 25 lpd of water for drinking purposes. In case of cooking, the utilisation of water is reported to be around 10 lpd by 22 per cent of the households, followed by 30 lpd as reported by 18 per cent households.

Around one-third (32%) of the study population reported consumption of 100 lpd of water for bathing, followed by 200 lpd as reported by 20 per cent. A negligible share of households (8%) reported consumption of 150 lpd of water for bathing. More than one-fifth (23%) of the study population reported consumption of 50 lpd of water for toilet and MSC followed by 100 lpd as reported by 20 per cent.

More than one-third (35%) of the study population said that they do not utilise water for cattle drinking. However, around 15 per cent households reported that they use around 10 lpd of water for cattle drinking. A little less than half of the study population (47%) reported not consuming water at all for agriculture and horticulture. More than one-sixth (18%) reported consuming 10 lpd of water while 5 per cent each of the study population reported consuming 25 lpd and 50 lpd of water for agriculture / horticulture.

3.10.1.4 Awareness about Desalination Technology

This section presents the findings pertaining to the perceptions of the study population regarding LTTD and RO technologies. The key insights from the primary survey are the following.

- The study population was asked whether they are aware of LTTD process used for water desalination and treatment. The entire study population (100%) replied in the affirmative.
- The study also attempted to understand if there was any prevalence of chemicals or effluents in the water that was used in the households in Kavaratti Island when RO plant was in operation. A little less than one-fifth (18%) of the surveyed population replied in the affirmative. Those who replied in the affirmative were further asked about the ways in which those chemicals or effluents were disposed off. The topmost responses were 'cleaning water by boiling' and 'mixing chlorine into the water and wait till the chlorine gets settled down'.
- Awareness of storage and maintenance of chemicals used in RO plant. However, regarding storage and maintenance of chemicals used in the plant, almost all of the study population said that they were not aware of the method of storage and maintenance of chemicals used in the plant.
- Awareness of labour force required for RO plant. More than one-fourth (28%) of the study population reported that around 5–10 people are required to maintain the RO plant followed by 23 per cent reporting 11–15 people. The average number of labour force required for RO plant, as reported by the study population, is 16.
- Ever noticed any chemical or discharge in sea water? The study population was asked whether they had noticed any chemical or discharge in the sea water. More than half of the study population (53%) replied in the affirmative. The study population who reported noticing chemical or discharge in sea water were further probed about the discharge affecting the local fishermen residing in the area. All replied in the negative.

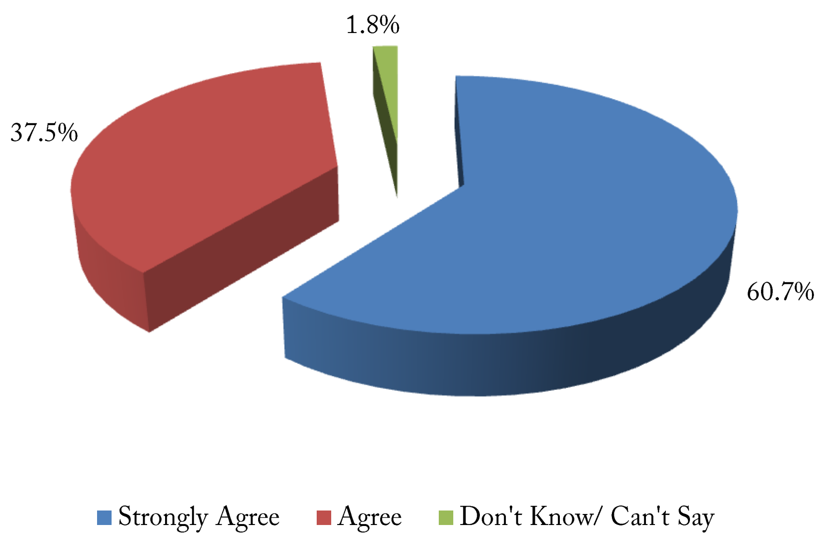
3.10.1.5 Socio-economic Impact of Using LTTD Technology

The study attempted to understand the perception of the people in the island on changes in their lives since the introduction of LTTD process. Most of the study population (93%) confirmed that there has been some change in the day-to-day lives because of using LTTD technology for desalination. The kind of changes reported by the study population range from regular access of good quality water, reduction in the prevalence of low blood pressure, better health conditions, reduction in water-borne diseases such as jaundice and diarrhoea, and reduction in hardness of water.

A. Standard of living

The study enquired of the people whether introduction of LTTD technology has made a change in their standard of living. More than 60 per cent of the surveyed population 'strongly agreed' that their standard of living has changed for the better after introduction of LTTD technology. Figure 3.6 presents the survey findings.

Figure 3.6: Perception of Study Population Regarding Changes in Standard of Living since Introduction of LTTD in Kavaratti Island, Lakshadweep



Source: Primary Field Survey, NCAER, 2012 (April)

B. Water-borne diseases

The survey also attempted to understand if there was prevalence of water borne diseases in the area before the introduction of the process of LTTD. While more than half (53%) of the study population replied in the affirmative, the remaining 47 per cent responded negatively.

'Dysentery' (88%), 'Typhoid fever' (13%), 'Amoebiasis' (6%) and 'Cholera' (6%) are the topmost water-borne diseases reported in the survey area before the introduction of LTTD. In contrast, almost negligible (2%) share of the study population reported that there are water-borne diseases prevalent in their area after the introduction of LTTD. Thus it can be concluded that the LTTD process for desalination has impacted the people living in the surrounding areas of the desalination plant in a positive way by reducing water-borne diseases.

C. Healthcare treatment

As part of the survey, effort was also made to look at availability of options for healthcare and treatment of water borne diseases in the area before the introduction of LTTD. Most of the study population (98%) reported that the existing government healthcare staff in their area suffices the need for healthcare treatment for the prevalent water-borne diseases. All the study population also reported that doctors are generally available at the government healthcare facilities. However, it is expected that residents of the islands would rather not suffer from water borne diseases rather than have doctors at the facilities.

3.11 Barge-mounted LTTD Plant, Chennai

NIOT has demonstrated an experimental 1000 cubic metre/day (1 million lpd) floating barge mounted LTTD desalination plant 40 km off Chennai coast meant for mainland usage. Floating plants are needed since the required depth of 400 m below sea level is only available beyond 40 km from the mainland. Temperature gradient of about 18°C was utilised with surface water at 28°C and the water at 550 m depth at 10°C. The plant was commissioned in April 2007 and the sea trials were successfully conducted for a few weeks.

The barge with the plant and the mooring buoy are shown in Figure 3.5.

Figure 3.7: A View of the Barge-Mounted Desalination Plant

Source: NIOT

3.12 Concluding Remarks

- Water is a unique natural resource as it is life sustaining. The projected water requirement in India by 2025 is 973–1180 BCM which exceeds the projected supply of water. Therefore, desalination of sea water for household consumption and industrial use is gaining importance as a measure to augment India's water resources.
- In this context, the technology policy for choice of desalination technology becomes quite relevant. This choice must include considerations of cost, efficiency, as well as environmental and ecological side effects of the technology.
- There are two main variants of desalination technology—thermal technology (encompassing LTTD, MED and MSF) and membrane-based RO technology. The analysis reveals that LTTD technology is way forward in coral islands, in spite of higher energy consumption vis-à-vis RO on account of the following reasons:
  1. LTTD does not involve the discharge of brine solution into the sea, hence is eco-friendly. This helps protect the interests of the vulnerable fishermen in the area, the major stakeholders in the island economy.
  2. The technology is maintenance free, and can be easily operated by less skilled labour.
  3. It is a stand-alone technology.

- RO is suitable for human consumption only when blended with thermal desalinated water. RO desalinated water cannot be stored for a long time.
- Thermal desalination should also be the preferred technology for coast-based power plants, iron and steel plants, and paper and pulp industry. In the medium and small scale category, industries that would call for use of thermal desalinated water in coastal areas and RO based desalinated water in interiors include dyes and chemicals and the leather industry.
- Introduction of LTTD has significantly improved the standard of living of the inhabitants of Kavaratti, according to the NCAER survey. An overwhelming 93 per cent of respondents agreed with this assessment. They also reported that there was no discharge of chemicals that had an adverse effect on ornamental fish available as a wild variety in the coral island. Incidence of water borne diseases has also fallen, according to the results of the same survey.
- The cost of desalinating a litre of water using LTTD technology in Kavaratti comes to around 77 paise if the project is to yield an economic IRR of 12 per cent. The ecological impact is minimal and the environmental effect, on account of higher energy consumption, is quite negligible viz 0.23 paise per litre.
- In the case of Thoothukodi Power projects, adoption of RO process entails a huge ecological cost (ranging from 14 to 43 paise per litre. The LTTD emerges as the best alternative due to the eco-friendly nature of the technology.)

Economic Benefits of Lobster Culture and Crab Fattening

Preamble

The present study examines the technology used to culture lobsters and mud-crabs in an open sea environment which is more an application of marine biology. The objective is to examine whether this augments the income of fishing households involved and to examine ways to scale up the experiment for an increased penetration. However, NIOT's main interest is to ensure that sufficient seeds are available for breeding to the juveniles stage through an application of bio-technology. This process is still in the development stage and thus, we have restricted our analysis to examining the technology to culture lobsters and mud-culture in the open sea environment.

Chapter 4
Economic Benefits of
Lobster Culture and Crab Fattening

4.1 Lobster Culture

4.1.1 Introduction

Lobsters are one of the most attractive and economically important premium seafood delicacies across the globe. Being a highly priced seafood item, lobster fetches the highest unit value among a variety of sea foods in the international market. As in the case of shrimp, the price structure of lobster varies according to their sizes. In India also, it forms one of the most valuable low volume fisheries in the coastal areas. There has been an increase in demand for both live and whole-cooked lobsters in the South East Asian countries in recent years. This has resulted in an enhancement in fishing activity and farming of lobsters in India.

High demand for live lobsters in the export market has generated considerable interest in culture / fattening of spiny lobsters. Tropical spiny lobsters are adaptable to captive conditions, less cannibalistic (feeding on the flesh of others of its kind) and relatively fast growing than their counterparts in the sub-tropical regions. Spiny lobsters have the ability to mature and breed in captivity and they can be grown communally. As a result, their commercial culture is taken up in many parts across the globe. However, the hatched out larvae take several months to metamorphose and develop into early juvenile stage. Large scale collection of post-larvae or puerulii is extremely difficult in India to initiate lobster culture, since it is difficult to collect large numbers from a particular region. The challenges being faced in lobster farming are the non-availability of puerulus stage in sufficiently large numbers and the considerably lengthy culture period taken by lobster seed to reach harvestable size. Hence, most lobster culture ventures in India involve collection of lobster juveniles from nature and growing them to the required size. About a third of our commercial catch is undersized juveniles. These juveniles are utilised for lobster culture / fattening. Moreover, fattening of big size lobsters is also done for two to three months to increase their "grade" in the live export trade.

Few fishers in India were engaged in lobster fishing on the southeast and southwest coasts until the development of the “whole cooked lobster” (whole lobster boiled / steamed and frozen) export trade to Japan in 1984. It resulted in a significant increase in value of small lobsters attracting more fishers into the trade. The advent of live export in the 1990s resulted in the harvest of more juveniles and sub-adults. Many coastal communities joined the fishery industry, resulting in the harvest of more juveniles and sub-adults. However, it also had some adverse impact in terms of exploitation of juvenile lobsters. To halt this trend, the government of India prohibited export of spiny lobsters below 200 g and of slipper lobster below 150 g in 2003. Enforcement of the minimum legal size for export of four commercially important species of lobsters in the country (Table 4.1) is considered to be a positive step taken by the Ministry of Commerce and Industry, Government of India. Implementation of the minimum legal size for fishing, closure of spiny lobsters fishery during the peak spawning season in the southern region, and a ban on trammel nets are some other regulatory measures recommended for implementation by different state governments.

Table 4.1: Medium Legal Size for Export of Lobsters from India, July 2003

Species	Live/chilled/frozen (g)	Whole cooked (g)	Tail (g)
Panulirus polyphagus	300	250	90
P. homarus	200	170	50
P. ornatus	500	425	150
Thenus orientalis	150	-	45

Source: Ministry of Commerce & Industry, GoI

NIOT successfully developed and disseminated the viable technology for fattening lobsters in sea-cages in the coastal areas of Tamil Nadu and Andaman Islands, on an experimental basis, starting from 2003. For this programme, NIOT designed and deployed floating sea cages in selected locations along the southeast coast of India to grow spiny lobsters. The main objective of this chapter is to study and assess economic benefits of lobster fattening activity among the fishermen communities in India and its potential as an alternative source of income generation. To fulfil this objective, a field survey was conducted by NCAER in April 2012, among the fishermen who underwent training on lobster fattening provided by NIOT in Thoothukodi district in Tamil Nadu. Specifically, the survey attempted to assess the appropriateness of availability of the technology provided by NIOT and its benefits as perceived by these fishermen. It is evident from the survey that only around one-third of the people were benefited from the training provided by NIOT. One of the important findings was the observation that for almost two-thirds of the people, the training on lobster fattening has not proved to be helpful. The reason for this for majority of the people was very high initial capital cost, which they were not able to afford. Lack of enough capital to pursue lobster fattening was one of the main reasons reported by more than 80 per cent of the people for feeling that the training provided was not helpful. Moreover, difficulty in maintaining cages, high cost of setting up cages and lack of adequate expertise are some of the other important reasons for people not being able to scale up this initiative. Moreover, some of the fishermen who were initially involved in lobster fattening activity have presently stopped the activity.

Overall, it is observed from the field visit that the fishermen are very much interested in taking up lobster fattening as an additional source of livelihood generation. Moreover, the economic benefits and return of investment are also considerably high. However, because of very high capital costs involved, not many have been able to scale up this initiative to a commercial venture. Therefore, even though lobster fattening has a great potential in these coastal areas, it will be successful only when the people receive support and handholding either from the government in terms of an SPV or from a non-governmental organisation (NGO) at least for a few years initially. Support is required in terms of setting up of cages that involve minimum maintenance costs and arranging seed / feed for the juvenile lobsters. A small section of the people also informed that they would require bank loan to pursue this activity further.

The structure of this chapter has been conceived hereafter as under:

- Lobster culture and fattening methods
- Lobster culture/fattening in sea-cages in Tamil Nadu
- Economic benefits of lobster fattening: Households' perception based on primary field survey in Tamil Nadu
- Summary/recommendations

4.1.2 Lobster Culture and Fattening Methods

Lobster fishery industry in India mainly constitutes of broadly two types: (a) spiny lobsters, and (b) slipper or sand lobsters.

(a) **Spiny lobsters**: Spiny or rock lobsters have a sub-cylindrical body with long cylindrical antenna with whip like flagellum. The carapace is covered with numerous spines and tubercles. Eight species of spiny lobsters, six shallow water and two deep sea, are generally found in India. *Panulirus polyphagus*, *P. homarus* and *P. ornatus* are the three commercially important species of shallow water spiny lobster occurring along the Indian coast. *P. polyphagus*, the mud spiny lobster, pre-dominates the fishery along the Maharashtra and Gujarat coasts occurring in depths less than 40 m. *P. homarus*, the scalloped spiny lobster, is mainly distributed along Kerala and Tamil Nadu coasts, inhabiting shallow waters (1–5 m) in rocky areas. *P. ornatus*, one of the largest of the *Panulirus* species occurs in large numbers along the southeast coast of India. While the former two species grow to a weight of about 1.5 kg, *P. ornatus* grows to more than 3 kg.

(b) **Slipper or sand lobsters**: The slipper or sand lobsters have a flattened body and short scale-like antenna without whip like flagellum. Commonly, two species of slipper or sand lobsters are found in India that are used for further culture.

Maharashtra and Gujarat are the main lobster fishing states followed by Tamil Nadu. While lobsters are landed as a by-catch in fish or shrimp trawls in the north-west coast, they are caught by gillnets, traps and occasionally by trawls in the south-east and south-west coasts. *Panulirus ornatus* is the most suited species of lobster for culture and fattening along our coastal region because of its faster growth rate and because it attains sexual maturity only after reaching a weight of about 700 g. In Gujarat, lobster culture initially became popular in Bhavnagar district. Juvenile lobsters are caught using stake net from shallow coastal waters. These juveniles are grown in small ponds covered with nylon nets in the intertidal region of the beach. The tidal flow of water helps in cleaning these shallow ponds. Juveniles weighing 40 to 50 g gain twice the weight in three to four months. Lobsters weighing 200 to 300 g are best suited for frozen or whole-cooked product while those weighing over 300 g (greens) and 500 g (tiger) are in demand for live lobster export. Generally, when the lobsters reach a weight of over 500 g they are exported live to the Southeast Asian countries. There is only one widely accepted method of lobster culture / fattening practiced in coastal areas of India which is briefly explained below:

Lobster culture / fattening in sea cages: NIOT, Chennai, successfully developed and disseminated the viable technology for fattening lobsters in sea-cages in the coastal areas of Tamil Nadu and Andaman Islands, on an experimental basis, starting from

2003. For this programme, NIOT designed and deployed floating sea cages in selected locations along the southeast coast of India to grow spiny lobsters. There has been a substantial improvement in earnings of coastal fishermen due to implementation of this scheme.

4.1.3 Lobster Fattening in Open Sea Environment

In 2003, NIOT initiated a programme to farm lobsters in sea cages as a livelihood security programme for coastal fishers along the south-east coast of India. For this programme, NIOT designed and deployed floating sea cages at Tharuvaikulam (Thoothukodi district), Kulasekharapatinam, Erwadi, and Parangipettai (Cuddalore district) along the southeast coast of India to grow spiny lobsters. Lobster farming was initiated at Tharuvaikulam, an open sea site, in May 2003. It was subsequently conducted at three other sites, two in the open sea (Erwadi, April 2004 and Kulasekharapatinam, April 2006), and one in a creek (estuary) (Parangipettai, March 2005). Six field trials, five with juveniles and sub-adults and one with pueruli and post-pueruli, were conducted at Tharuvaikulam, one each with juveniles at Erwadi, Kulasekharapatinam, and Parangipettai (juveniles and sub-adults).

4.1.3.1 Details of Culture/Fattening Initiative

Sea cage design and deployment at the site

Floating cage designs were chosen by the coastal fishing communities for their ease of operation. The mild steel cages deployed initially had a main frame of 75 mm diameter galvanised iron pipe with steel woven mesh (50 mm x 50 mm), which accommodated four inner cages. The inner cages had two layers of nylon mesh. The frame had four buoyancy modules made of polyethylene containers of 200 litres each filled with polyurethane foam. Cages were fitted with sacrificial zinc anodes. Each frame was moored with two lightweight (10–15 kg) anchors, connected to the centre of the cage frame at the bottom with a swivel, at 2–3 m depth. The metallic body was painted with non-toxic, polymer-based paint (International Paints Ltd, Akzo Nobel, Netherlands) with antifouling properties. Three cages were made with eight inner cages by dividing the inner compartments horizontally into two halves, placed one above the other. At Tharuvaikulam, fishers fabricated mild steel cages without inner compartments and placed them on the sea floor near to low tide level at about 1.2 m depth. The legs of the cages were fixed in concrete blocks to keep them in position.

Subsequent designs used fibre reinforced plastic to improve handling and durability of the cages. Each fibre-reinforced plastic cage was 1 m x 1 m x 1 m with a float of 1.4 m x 1.4 m x 0.2 m made of marine food grade isophthalic resin, reinforced with glass fibre. The fibre-reinforced plastic float was strengthened and filled with polyurethane foam and stainless steel anchoring hooks. The thickness of the cage wall was 5 mm and that of the float 2 mm. The sidewalls contained 25 mm circular perforations and the bottom had 10 mm diameter openings. The sidewalls were subsequently replaced with 5 mm thick and 25 mm wide pultruded fibreglass strips arranged in vertical and horizontal rows, 25 mm apart, to increase the strength and flushing rate. Each cage was provided with stainless steel hooks (to lift it) and a perforated fibre-reinforced plastic lid. Floats of four cages were tied together with 8 mm nylon rope with one of the cages connected with 15–20 mm nylon rope to a lightweight (10–15 kg) anchor mooring to cages at 2–3 m depth. No swivel was used to connect the anchor to the cage. Except at Erwadi, where three cages were used for the trial, four cages were used for each trial at all other sites, except for pueruli and post-pueruli which were grown in only one cage at Tharuvaikulam (trial 1). Two mild steel cage units, each with four inner cages, were first deployed at Tharuvaikulam in May 2003. The first fibre-reinforced plastic cage (two units of four cages each) was also deployed at this site in January 2004. Three fibre-reinforced plastic cages were deployed at Erwadi in April 2004, four at Parangipettai in March 2005, and four in the open sea at Kulasekharapatinam in April 2006. All cage trials were conducted between May 2003 and May 2007 at these sites. At Kulasekharapatinam, the fibre-reinforced plastic cages were deployed in the wave breaking zone and each cage had to be moored with an anchor, whereas one anchor for four cages in a unit was used at the other sites.

Stocking of lobsters

Juvenile (<90 g) and sub-adult lobsters (90–150 g) from the regular fishery were used for farming in cages. Pueruli, post-pueruli, and early juveniles settled inside and outside the cages and at the bottom below the cages at open sea locations within two months of stocking in cages, and were also used for subsequent stocking at Tharuvaikulam in August 2003. *Panulirus homarus*, which constitutes the main fishery on the southeast coast, was the main species used, whereas *P. ornatus* juveniles, caught in lesser quantity in these areas, were stocked in small numbers (n = 4-24), with *P. homarus*, only in three trials (four cages each) at Tharuvaikulam and in one trial (three cages) at Erwadi. *Panulirus homarus* and *P. ornatus* were grown together and their growth rates were calculated separately while combined stocking densities were expressed for both. Measurements of wet weight (0.01 g accuracy) and carapace length (0.01 mm accuracy) of lobsters were taken at the beginning, at the time of monthly sampling, and at the end of the trails. Weights presented are wet weights.

Five juvenile / sub-adult lobster trails were conducted in mild steel cages at stocking densities ranging from 21 to 38 individuals per sq m at Tharuvaikulam. The stocking density of pueruli and post-pueruli (1.58 + 0.62 g and 1.58-0.62 g) was 60 individuals per sq m at this site. Initial lobster weights ranged from 60 to 160 g in all trials except for one in which naturally settled pueruli and post-pueruli (0.40 to 1.95 g) were stocked. Grow-out trials were conducted in fibre-reinforced plastic cages with a stocking density (lobster weight 30–150 g) of 50 individuals per sq m at Parangipettai and Kulasekharapatinam. At Erwadi, it was at 80 individuals per sq m. The duration of the grow-out trials ranged from 60 to 266 days.

Sampling

Monthly measurements included carapace length (mm) and wet weight (g) of lobsters to monitor survival and growth. All four stages in a unit were stocked at the same rate, but measurements were taken only from one of the cages at monthly intervals owing to logistic constraints. Measurements of all lobsters in the same marked cages were taken during sampling. Lobsters in the other three cages were measured only at the beginning and end of the trials. The growth of lobsters in marked cages was compared with that in the other cages at the end of the trials.

Lobsters were fed once a day in the evenings. Marine clam, Donax spp., collected from the intertidal zone near the cage sites, was the main food. Other foods, like meat of the gastropod, *Xanchus pyrum* (at Tharuvaikulam), marine crab (*Charybdis* sp.), mantis shrimp (*Squilla* sp.), fish (clupeids and *Leognathus* sp.) and squid (*Loligo* sp.), collected by fishers during their daily fishing voyages, were fed when clams were in short supply. Green mussel, perna viridis, was cultured at Tharuvaikulam and also used to feed lobsters. Feeding was monitored at fortnightly or monthly intervals and the feed ration was revised, accordingly to total biomass measured in each cage. The exact quantification of food was not possible, but ranged between 5 and 10 per cent wet body weight per day at all sites, except at Parangipettai where lobsters were underfed initially for two months. Empty clam and mussel shells were removed once a week and the cages were cleaned once a month with a scrub brush to reduce fouling by algae, barnacles, and other organisms.

Growth calculation
Percentage weight gain, weight increase per day and specific growth rates (SGRs) were used to compare the different size groups, stocking densities and sites:

i. Weight gain (%) = (Final mean lobster weight – initial mean lobster weight) * 100 / initial mean lobster weight;
ii. Weight increase (g per day) = (Final mean lobster weight – initial mean lobster weight) / number of days; and
iii. SGR (% body weight per day) = (log normal final mean lobster weight – log normal initial mean lobster weight) * 100 / number of days.

Puerulus collectors
Entry of pueruli and post-pueruli was recorded at monthly intervals from January to December 2004 in one of the marked cages at Tharuvaikulam. Three habitat type puerulus collectors (Booth 1978, without the closed box arrangement to prevent escape of settled pueruli while lifting) and six Mangalore tile collectors (corrugated roofing tiles, 30 cm x 20 cm with coir rope wound around it) were also used to study puerulus settlement between April and July 2004 at this site. These collectors were suspended near the cages at 1 m depth. Puerulus settlement was examined, on the collectors and in the cage, at the same time as monthly measurements.

Water quality management
Water quality measurements were taken between 900 and 1100 h at each site during sampling with a thermometer, refractometer (salinity, +0.1 to -0.1 PSU), and pH meter. Continuous temperature recording at three-hourly intervals were obtained from a data buoy (NIOT) moored at 12 m depth at Thoothukkodi fisheries harbour, located between Tharuvaikulam and Kulasekharapatinam.

4.1.3.2 Results of Culture/Fattening Initiative
Survival and growth of **P. homarus**
Data on stocking density and survival of pueruli and post-pueruli, juveniles and sub-adults of *P. homarus* at three open sea farming sites and the creek site showed that an increase in stocking density from 21 to 80 individuals per sq. m did not affect survival. During one trial at Tharuvaikulam, 70 per cent of the pueruli and post- pueruli survived until the end of the experiment (266 days). Survival was 72 ± 6 per cent to 100 per cent for juveniles and sub-adults during other trials at this site. Survival of juveniles was 81 ± 6 per cent at Erwadi and 90 ± 5 per cent at Kulasekharapatinam. The lowest survival, 49 ± 7 per cent, was at the creek site at Parangipettai. Lobster density at harvest (end of the trails) was higher than at initial stocking at the open sites owing to entry of post-pueruli into the cages. Measurements of initial stocks were only taken at monthly intervals for growth and survival estimates, but new entries were not removed from the cages. New entries of pueruli and post-pueruli were distinguished by the difference in their size in relation to the initially stocked lobsters.

Survival and growth of **P. ornatus**

Compared with *P. homarus,* the number of *P. ornatus* used in the trials was less (4 to 24 for each trial). All were juveniles (71 to 165 g wet weight) as this species matures at 1000 g body weight. The results of three trials at Tharuvaikulam and one at Erwadi showed that the daily growth rate (g per day) of *P. ornatus* juveniles increased whereas the SGR decreased with size. The daily growth rate increased from 0.94 ± 0.33 g in 71.0 ± 21.8 g lobster (n = 12) to 1.18 ± 0.11 g in 165.0 ± 9.6 g lobster (n = 4), whereas the SGR decreased from 0.70 to 0.43. Of the three trials at Tharuvaikulam, 100 per cent survival was recorded in two and 85 ± 4 per cent survival in the remaining one, whereas 81 ± 5 per cent survival was achieved at Erwadi.

Puerulus settlement

Settlement of *P. homarus* pueruli and post-pueruli was first observed, both inside and outside the cage, during the second month of farming at Tharuvaikulam in June 2003. Even through settlement occurred almost throughout the year, the peak settlement period was from March to April in 2004 with a second peak in July. Thirty five pueruli and post-pueruli were collected in April 2004 from the cage. Puerulus settlement was also observed in habitat collectors and Mangalore tile collectors at Tharuvaikulam during April to July 2004. A maximum of six pueruli were collected from one of the habitat collectors and two from Mangalore tiles during sampling in April 2003, but the exact quantification of settlement in these collectors was not possible as some pueruli escaped while the collectors were hauled to the surface. Small juveniles were also found attached to the cage and on the sea floor underneath it.

Table 4.2 presents the detailed results of the initiative by NIOT.

Table 4.2: Stocking Density, Survival and Growth of Pueruli and Post-Pueruli, Juveniles and Sub-Adults of P. homarus and Juveniles of P. ornatus at Three Open Sea Farming Sites and a Creek Site in India between May 2003 and May 2007

A. *P. homarus*

Tharuvaikulam –open sea (mild steel cage)	Stocking density (No./sq mt)/No. of replicates	Sample size (n)	Days	CL initial (mm)	Initial wt. (g)	CL final (mm)	Final wt. (g)	% survival	% wt. increase	% wt. increase/day	wt. increase g/day	SGR
1	60/1	33	266	19.00 ±2.08	1.58 ±0.62	48.14 ±3.66	123.1 ±26.22	70	7691.14 ±1660.49	28.71 ±6.24	0.46±0.09	1.64
2	50/4	28	94	45.72 ±2.33	77.50±14.79	54.21±4.59	146.44±32.37	100	88.95 ±41.81	0.95± 0.42	0.73±0.33	0.67
3	38/4	21	62	47.00 ±4.06	107.5±27.27	52.02±3.58	148.95±21.39	100	38.56 ±19.90	0.63± 0.32	0.67±0.35	0.53
4	38/4	11	91	48.78 ±4.72	111.70±29.91	56.83±2.08	175.00±10.80	72 ±6	56.71 ±9.68	0.63± 0.11	0.70±0.12	0.43
5	21/4	10	225	52.35 ±4.18	123.61±29.26	70.81±3.88	341.25±46.22	73 ±4	176.07 ±37.39	0.78± 0.17	0.97±0.20	0.45
6	28/4	10	132	51.69 ±2.68	138.10±19.68	63.11±4.90	245.00±51.96	72 ±4	77.37 ±38.18	0.59± 0.30	0.81 ±0.39	0.43
Parangipettai – creek (FRP cage)	50/4	50	190	48.58±4.93	107.19±34.48	53.91±3.92	170.68±35.48	49 ±6	59.23 ±28.14	0.31± 0.15	0.33±0.18	0.15
Kulasekharapatinam – open sea (FRP cage)	50/4	50	98	38.12±6.77	58.21±28.22	53.19±4.31	149.79±32.98	90 ±6	157.33 ±56.12	1.61± 0.58	0.97±0.34	0.96
Erwadi – open sea (FRP cage)	80/3	56	155	36.93±2.91	51.83±10.32	57.84±3.98	184.91±39.30	81 ±4	256.76 ±67.22	1.66± 0.45	0.86±0.25	0.82

B. *P. ornatus*

Tharuvaikulam – open sea (mild steel cage)	Stocking density (No./sq mt)/No. of replicates	Sample size (n)	Days	CL initial (mm)	Initial wt. (g)	CL final (mm)	Final wt. (g)	% survival	% wt. increase	% wt. increase /day	wt. increase g/day	SGR
6	28/4	6	164	42.94 ±2.87	71.00± 21.77	62.43 ±5.62	225.00±55.23	100	216.90 ±77.47	1.32±0.47	0.94±0.33	0.7
4	38/4	10	164	46.07 ±1.55	95.00± 7.07	65.65 ±4.05	257.5±37.50	85 ±5	171.10 ±38.95	1.04±0.23	0.99±0.23	0.61
5	21/4	4	255	55.12 ±2.08	165.00± 9.61	76.51 ±3.81	430.00±22.22	100	160.60 ±68.90	0.71±0.30	1.18±0.11	0.43
Erwadi – open sea (FRP cage)												
	80/3	24	155	42.12 ±6.02	76.35±34.50	61.50 ±4.90	215± 48.41	81 ±5	181.60 ±84.95	1.17±0.54	0.89±0.32	0.67

Source: New Zealand journal of Marine and Freshwater Research, 2009, Vol. 4

Notes: FRP: Fibre reinforced plastic; CL: Carapace length; SGR: Specific growth rate, CL and weight (wet weight): average ± SD

4.1.4 Financial Benefits of Lobster Fattening: Households' Perception Based on Primary Field Survey in Tamil Nadu

As part of the present study, NCAER conducted a primary field survey in the coastal area of Thoothukodi district in Tamil Nadu. More specifically, the study was carried out in two locations in Thoothukodi, i.e. Kulasekharapatinam and Tharuvaikulam, where training on lobster culture / fattening was provided by NIOT. The prime objective of the study was to assess the perception of household population regarding benefits of lobster fattening. It also focused on the economic impact of lobster fattening in Thoothukodi in Tamil Nadu.

Primary Field Survey: Coverage

The target group for the quantitative survey comprised the household population who underwent training provided by NIOT on lobster culture / fattening in Thoothukodi. In total a sample size of 54 households (one chief wage earner per household) were surveyed as part of this field study. Semi-structured questionnaires were used to collect the required information from people trained in lobster culture / fattening.

Demographic and Socio-economic Profile of Study Population

This sub-section presents the demographic and socio-economic profile of the study population.

A. Age distribution

More than two-fifths (43%) of the sample population is in the age group of 31–40 years while one-fourth (26%) each in the age group of 21–30 years and 41–50 years. The average age of the sample population was found to be around 37 years.

B. Educational attainment

Half of the sample population has completed primary level of education, around 24 per cent has completed middle level, and about 15 per cent has completed secondary level.

C. Occupation

Majority of the sampled population (more than 90%) work as skilled workers, while 4 per cent are unskilled workers.

D. Family income

The average monthly household income of the sampled household is observed to be between Rs 8500 and Rs 9000 (Rs 8870). Around 45 per cent each of the households reported that their household income is in the range of Rs 8001–10000 and Rs 6001–8000. Around 6 per cent of the sample population reported their monthly household income is more than Rs 10000.

Training on Lobster Fattening from NIOT

The sample population was asked whether they were aware of the lobster culture / fattening before the NIOT intervention. Most of the people (98%) replied in the affirmative while only 2 per cent reported 'no awareness'. The survey also attempted to understand the various aspects covered during the training provided on lobster fattening or converting juvenile lobsters into market lobsters. It was found that the different aspects of the training ranged from ways of earning better income and improving economic conditions through lobster fattening, methods of juvenile lobster cultivation, and ways of exporting juvenile lobster seeds overseas.

Of the total population who received training from NIOT, only more than one-third (37%) felt that the training was beneficial to them. They were further probed about the reasons for feeling that way. All reported that the training helped them in getting higher price for lobster and that they learned about the process of converting juvenile lobster into market lobster. The sample population who got training and pursued lobster fattening were asked whether it helped them to get better prices for lobster in the markets. Around one-third (30%) of them reported that it helped them in getting better prices for lobsters.

Restrictions in Scaling Up Lobster Culture
One of the important findings of the field visit was the observation that for almost two-thirds of the people, the training on lobster fattening has not proved to be helpful. Those reporting that the training was not helpful were asked about the reasons for feeling so. Majority of these people replied that the initial capital cost to take up this activity is very high, which they were finding very difficult to afford. Lack of capital to pursue lobster fattening is one of the main reasons reported by more than 80 per cent of the people for feeling that the training provided was not helpful. Moreover, difficulty in maintaining cages, high cost in setting up cages and lack of adequate expertise are some of the other important reason for people not being able to scale up this initiative.

More than one-fourth (26%) of the sample population reported that they still continue the process of converting juvenile lobster to market lobster. Around 9 per cent reported not pursuing lobster fattening. Those reporting discontinuation of lobster culture / fattening were further probed about the reasons for the same. 'Cages are difficult to maintain' (13%), 'setting up of cages is expensive' (10%), and 'help needed in lobster culture / process' (8%) are the topmost reasons for discontinuation.

Financial Benefits of Lobster Culture
This sub-section presents the findings on financial economic benefits for households from pursuing lobster fattening as an additional livelihood generating activity.

A. Increase in household income
The sample population reporting increase / change in price of lobster was further probed about the increase in average household (HH) income after taking up lobster culture / fattening. The analysis indicates that the range of average monthly HH income was Rs 400 to Rs 6000 before lobster fattening while after lobster fattening the range of HH income increased from Rs 996 to Rs 60,000. About 13 per cent of the study population reported Rs 5000 as the monthly HH income before lobster fattening while 15 per cent reported Rs 10000 as the monthly HH income after taking up lobster fattening.

The weighed average household income before lobster fattening was around Rs 3546 which increased to Rs 14,841 after taking up lobster-fattening.

B. Potential for commercialisation

One-sixth (15%) of the sample population reported that there is potential to a great extent, followed by 11 per cent reporting potential to a moderate extent. About 2 per cent of the study population reported that there is a little potential for commercialisation of lobster fattening. Seven per cent felt that there is no potential for the same.

Calculation of the Present Value of Benefits

A. Number of cycles, time period and number of cages per cycle

The sample population pursuing lobster fattening were asked about the number of cycles of lobster fattening, time period needed per cycle and number of cages used per cycle. About 35 per cent reported 4 as the number of cycles of lobster fattening. More than one-third (35%) reported 90 days as the period needed for converting juvenile lobster to market lobster per cycle. Regarding number of cages per cycle, one-third (32%) of the study population reported that one cage is used per cycle.

The following parameters were used in the analysis.

B. Change in price before and after lobster fattening

The study population was asked about the change in price of lobster before and after fattening. More than one-tenth (11%) reported that before lobster fattening activity they used to get Rs 500 per kg of lobster while 7 per cent reported Rs 550 per kg. After taking up lobster fattening, the price they got ranged from Rs 1200 to Rs 2200. About 11 per cent each reported Rs 1500 per kg and Rs 2000 per kg of lobster.

C. Period over which change in price (FOB realisation) of lobster occurred

The people who reported change in price of lobster before and after lobster fattening were further asked about the period over which this increase / change occurred. More than one-fifth (22%) reported that it was realised immediately after adopting the lobster culture while 11 per cent reported ‘six months after adopting the process of lobster culture’. Hence it can be noticed that families got an increase in the price of lobsters in a short period after adopting process of lobster fattening. About 2 per cent reported this change in price occurred after a year from adopting the process of lobster fattening.

D. Total cost of converting juvenile lobster per year

The sample population was asked about the total cost of converting juvenile lobster to market lobster per year. More than one-tenth (11%) reported Rs 3,00,000 as the total cost. About 6 per cent reported Rs 3,20,000 as the total cost and 4 per cent each reported Rs 2,40,000 to Rs 3,50,000.

Weight of juvenile lobster before fattening – 50 g
Price of juvenile lobster/kg – Rs 450–500
Number of cycles/year – 4
Number of cages/cycle – 1
Number of juvenile lobster/cage – 500
Weight of juvenile lobster after fattening – 250 g
Price of juvenile lobster/kg after fattening – Rs 1300 – Rs 2200
Cage price – Rs 6000 (at present provided by NIOT)
Cost of converting juvenile lobster/year – Rs 3, 00,000

Assumptions

Discount rate – 12%

Present value of benefits (useful life – six years) comes to Rs 32.12 lakh excluding cost of cage acquisition.

Expectations from NIOT and Similar Institutions
The sample population was asked about the expectations from institutions such as NIOT regarding various aspects of lobster fattening as a source of additional livelihood generation. Most of the study population (93%) reported that institutions should help in setting the cages while 87 per cent reported support in terms of getting better FOB for lobster. Around two-thirds (65%) of the people expressed their desire to have support from NIOT and similar institutions in updating the technology / lobster fattening.

The sample population who had stopped the lobster fattening activity was asked about the support they require from NIOT to re-start the activity. Most of the people responded that they need help in setting up cages, and arranging seed / feed for the lobster. A large section of these people said that they require bank loans to pursue this activity further. They want cages that do not rust or form algae very fast because it involves huge maintenance costs.

The survey also tried to understand whether anyone built the necessary cages for converting juvenile lobster to market lobster within the region. Around one-third (32%) of them replied in the affirmative. The people who reported that someone built the cages were further asked about the agencies / institutions who built them. Ninety four per cent of them reported NIOT followed by department of fisheries (65%). On the usefulness of the cages built, more than half (53%) of the sample population reported that the cages built by NIOT were useful.

More than half (59%) of the people reported that the cages built require modification. Modifications ranged from having fibre mixed nylon cages to cages that are fixed and do not rust. They also wanted to have nylon ropes since the present ropes break easily whenever there were waves in the sea.

4.1.5 Concluding Remarks

Lobster fattening using NIOT developed technology initiative can be a lucrative occupation according to the target households chosen for experimental implementation in Thoothukodi district. However, the target households feel that the training imparted by NIOT, though relevant, may not be useful as the households would require handholding and uninterrupted support for adoption of the technology. Besides, they would need to access funds to service their working capital needs as well as to acquire cages. *At present only around 1 per cent of households involved in fishing activities in two villages of Thoothukodi district have taken to this technology.* To scale up the project implementation efforts and to disseminate technology without any threat to loss of IPR, NIOT may have to enter into an exclusive MoA with NGOs like M S Swaminathan Research Foundation which have extensive hands-on experience in forming self-help groups. The NGO also has considerable project implementation experience to effect widespread adoption along Indian coastal areas.

4.2 Crab Fattening

4.2.1 Introduction

Crab fattening, more specifically mud-crab fattening, is widely practiced in many south-east Asian countries and in Australia. Mud crabs, or mangrove crabs, is a popular sea food item, which fetches high prices in domestic as well as international markets. It has become increasingly popular because of the quality of meat and the large size. Mud crabs have come into prominence in India since early 1980s when export of live crabs to South East Asian countries started. Because of its high demand in the export market, specifically for live mud-crabs, lot of interest in the production and fattening of mud crabs through aquaculture was created. Moreover, In India mud crab is an important secondary crop in the traditional prawn or fish culture systems in some of the coastal states and union territories. Mud crabs are reasonably tough animals and can be transported live and packed dry in boxes. This makes marketing and transportation much simpler than many other organisms.

Crab fattening is essentially stocking of soft shelled water crabs in smaller impoundments for 20–30 days till the shells are hardened and they flesh out. Fattening of the mud crab is being undertaken in the states of Andhra Pradesh, Tamil Nadu, Karnataka, Orissa, and West Bengal. The mud crabs inhabit marine as well as brackish environments. Culturing of mud crabs is not economical and hence crab fattening, being more profitable, is practiced.

The main objective of this Section is to study and analyse the socio-economic impact of crab fattening activity among the fishermen community in the Islands as an alternative source of income generation. To be specific, a field survey has been conducted in a few villages in Andaman Islands, where training on crab fattening was provided by NIOT during September to December 2004. The survey attempted to assess the appropriateness of the technology provided by NIOT and to understand the usefulness of training and technology provision.

It has been learnt from the survey that after the Tsunami of 2004, people in the island have stopped crab fattening altogether because of lack of enough capital to start off the activity again. Currently there is no crab fattening activity in the surveyed villages. The survey revealed that there is considerable potential for crab fattening, which is still left untapped because of financial issues. However, because of very high capital cost involved, not many have been able to scale up this initiative to a commercial venture. Setting up of cages is extremely expensive and there is lack of adequate financial resources for this purpose. Therefore, even though crab fattening has a great potential in these coastal areas, it will be successful only when people receive some initial support and handholding either from the government in terms of an SPV or from an NGO at least initially for a few years. Support is required in terms of setting up of cages, arranging seeds and feed for the juvenile crabs, and provision of training pertaining to crab fattening technology.

The structure of this chapter has been conceived as under:

- Crab aquaculture methods
- Technical parameters of crab fattening
- Evidence of crab fattening: Tamil Nadu and Andaman and Nicobar Islands
- Socio-economic impact of crab fattening: Primary field survey in Andaman and Nicobar Islands
- Summary/recommendations

4.2.2 Crab Aquaculture Methods

Broadly, there are two species of mud crabs.

A. Large species
    - The larger species is locally known as `green mud crab'.
    - It grows to a maximum size of 22 cm carapace width and 2 kg in weight.
    - These are free living and distinguished by the polygonal markings present on all appendages.

B. Small species
    - The smaller species is known as `red claw'.
    - This grows to a maximum size of 12.7 cm carapace width and 1.2 kg in weight.
    - It is without polygonal markings and has a burrowing habit.

The Scylla species of mud crabs inhabit coastal areas, estuaries, and backwaters. *Scylla serrata* is much in demand in the domestic market and fetches good price, compared to other species. Medium and large crabs of more than 14 cm carapace width and weighing more than 400 g are collected exclusively for export purposes from West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra, Gujarat, and Andaman and Nicobar Islands.

There are two basic forms of land-based mud crab aquaculture:

1. Grow-out of juveniles to market size
2. Fattening of crabs with low flesh content / water crabs

Grow-out culture

Grow-out systems for mud crabs offers more scope and the production can be high. Grow-out systems are usually pond-based, with or without mangroves, although intertidal pens can also be used. However, this type of culture is not very popular in India and not practiced due to the non-availability of juvenile / seed crabs in sufficient quantity and the lack of good quality artificial feed.

Fattening culture

Soft shelled crabs are reared for a period of a few weeks till their exoskeleton gets hardened. These 'hard' crabs are locally known as "mud" (meat) and fetch three to four times higher price compared to soft crabs. Crab fattening is the most popular method of crab culture since the culture period is short and profitable, when enough stocking material is assured. Two popular methods of crab fattening are discussed below.

A. Fattening in ponds

Fattening can be done in small tidal ponds between 0.025–0.2 ha, with a water depth of 1 to 1.5 m. Before stocking the soft crabs in the pond, the bottom is prepared by draining the pond water, sun-drying and adding sufficient quantity of lime. Proper care is taken in strengthening the pond bunds without any holes and crevices. Special care is taken in the sluice area as these crabs have a tendency to escape through nearby areas of sluice gate. The inlet areas should be reinforced with bamboo matting inside the bund.

B. Fattening in pens and cages in sea

Fattening also can be carried out in pens, floating net cages or bamboo cages in shallow estuarine waterways and inside large shrimp ponds with good tidal water influx.

- HDPE, netlon or bamboo splits can be used as the netting material.
- The size of the cage would be preferably 3 m x 2 m x 1 m.
- The cages have to be arranged in a row so that feeding and monitoring can be done easily.
- A stocking of 10 crabs/m^2 for cages and 5 crabs/m^2 for pens is recommended. Since the stocking rate is higher in cages and to minimise the mutual attacks, the tips of the chelae can be removed while stocking.
- However, these methods are not commercialised like `fattening' in ponds.

4.2.3 Technical Parameters of Crab Fattening

Crab seeds are available in the nature in all sizes. Juvenile crabs can be collected from estuaries, lakes, backwaters, creeks, mangroves, and salt water lagoons by using bamboo traps, lift nets or scissor nets. Mud crab culture depends mainly on the natural sources for seed supply, and is, therefore, a major limiting factor for culture of crabs. The technical factors for crab fattening are discussed below:

A. Soil quality: Soil suitable for crab fattening is sandy clay as a sandy bottom discourages burrowing.

B. Water quality: Abundant and good quality water should be available. Mud crabs are highly tolerant to varying salinity conditions. Therefore, brackish water would be ideal for crab fattening operations. To carry out the activities of crab fattening, the water quality parameters have to be maintained in the following range (Table 4.3):

Table 4.3: Water Quality Parameters

Parameter	Range
Water Salinity	10–35 per cent
Water Temperature	25–35°C
Dissolved Oxygen	>4 ppm
pH	8.0–8.5

Source: http://www.mssrf.org/ecotech/ebook/et-pub-08.pdf

C. Water supply and drainage: Water exchange is through tides. Sluice gates may be used to regulate the inflow and outflow of the tidal water. The sluice gates are fitted with bamboo screens to prevent the escape of crabs. In regions where tidal influence is less, brackish / sea water is pumped in.

D. Stocking: Soft-shelled crabs of size 8 cm carapace width and above or crabs of more than 550 g are stocked with a stocking density of 1–3 crabs per m^2. Crabs of similar size are preferred so as to reduce cannibalism. Ponds can be divided into compartments so that crabs of the same size can be stocked together. Male and female crabs can also be stocked separately. Monoculture of crabs based on scientific practices yield better results.

E. Feeding: Crabs are fed with bivalve meat / trash fish with a daily ration at about 5–10 per cent of body weight (10 per cent during the first week). The duration of fattening is normally

20 days. Care should be taken to provide sufficient food for better growth and also to avoid cannibalism.

F. Harvesting: The expected survival rate is 70 to 80 per cent. Crabs are harvested after the shell hardens and before the next moulting. Harvesting can be effectively done in tide-fed ponds by letting in water through the sluice into the pond during high tide. As water starts flushing in, mud crabs tend to swim against the incoming water and congregate near the sluice gate. Crabs can be caught with the help of scoop nets and also by hand picking at the lowest low tide levels. Harvesting should preferably be done in the early morning hours or evening. Six cycles of fattening can be possible in a pond in a year.

H. Packing: Crabs should be washed and the first pair of chelate legs (the largest legs with pincers) of each crab should be firmly tied up to the body by either jute or nylon thread to avoid fighting and consequent injury. Care should be taken to keep the chelate legs intact and the threads not touching the eyes. These crabs are packed either in bamboo baskets or in perforated thermocole boxes for export. Moist conditions should be ensured while transporting crabs.

4.2.4 Evidence of Crab Fattening in Sea Water: Tamil Nadu and Andaman and Nicobar Islands

Crab fattening activity was adopted in Andaman and Nicobar Islands and in parts of Tamil Nadu as an alternative source of income generation. In Tamil Nadu, the initiative was taken up by M.S. Swaminathan Research Foundation (MSSRF), a non-profit research organisation, while these activities were funded and supported by NIOT, MOES in Andaman and Nicobar Islands.

A. Crab fattening initiative in Andaman and Nicobar Islands

Mud crab fattening through a training programme was adopted during September to December 2004, in Andaman and Nicobar Islands. It was initiated by Centre for Ocean Science and Technology of NIOT, Ministry of Earth Sciences. Pond culture method of crab fattening was implemented in the Islands. Tide fed ponds in Lakshmipur (North Andaman) and Bamboo Tickri (Middle Andaman) with mangroves such as *Avicennia marina, Rhizophora apiculata, R. mucronata, Nypa fruticans* (mangrove palm) and *Acrosticum auriam* were chosen for this activity.

Nature of pond and pond management

The length and width of each pond was 15×20 m, covering an area of 300 sq m. Both the ponds received freshwater influx during monsoon. The ponds were flooded with sea water during high tide up to a depth of 1.5 m and during low tide water flushed out and the depth reduced to 0.5 m. The ponds were fenced outside by bamboo mat of 2 m height with 40 cm driven into the soil to prevent escape of crabs by digging holes. Polythene sheet of 30 cm width was meshed with bamboo mat inside the pond at the top to prevent escape of crabs by climbing. Net with 1 cm mesh size (knot to knot) was fixed at the inlet of the pond to minimise entry of fishes which would feed on crab feed.

Salinity was measured every day by a handheld refractometer (ATAGO) and temperature with a thermometer of 0.1°C accuracy. The pH was measured with a pH meter (Eutech Instruments) and dissolved oxygen (mg/L; Winkler's method) once in a week.

The Process of crab fattening
Water crabs procured from local fishermen were transported to the fattening ponds and acclimatised to the pond conditions before stocking. Mounds were left in the centre of ponds to maintain mangrove species undisturbed which occupied approximately 60 per cent of the water spread area. The crabs made burrows inside the mounds and bunds for hideouts. In order to minimise mortality of crabs by cannibalism, clay pots and broken tyres were placed in the ponds as additional hideouts. Crabs were weighed individually and 61 crabs (*S. olivacea* – 37, *S. tranquebarica* – 16, and *S. serrata* – 8) were stocked at Lakshmipur (mean weight: 972 g) and 62 crabs (*S. olivacea* – 41, *S. tranquebarica* – 15, and *S. serrata* – 6) at Bamboo Tikri (mean weight: 990 g).

The approximate stocking density was 0.5 kg/sq m. Crabs were fed in the evening with trash fish and clam meat at about 8 per cent of total body weight. About 20 per cent of the feed was kept in check trays in the four corners and 80 per cent was broadcast in the entire area of pond. On subsequent days, the feeding rate was calculated based on the unconsumed feed in the check tray. If feed on the tray was consumed completely, the quantity was increased by 5 per cent of total feed on the next day. When residual feed was more than 5 per cent, the feed offered was reduced by 5 per cent. No changes were made in feed quantity if less than 5 per cent of feed was not consumed.

Harvesting
Harvesting of crabs commenced on the 30th day after stocking. Fattened crabs were partially harvested and less hardened crabs were released back into the pond for further hardening. The entire harvest was completed by the 35th day by handpicking.

B. Crab fattening initiative in Tamil Nadu

In 2006, MSSRF adopted an initiative with the objective of providing income-earning opportunities and fostering sustainable livelihood security of the fishing communities, agriculture farmers, widowed women, and orphaned children who were affected badly by the Tsunami. It is a micro-credit programme through self-help groups (SHGs) for the fishing communities to revive and diversify the livelihoods[2].

Role of Self-Help Groups in the process
Crab fattening activity was started in Madavamedu village in Sirkazhi Taluk of Nagpattanam district in August 2006. There were approximately 15 members in each SHG. Knowledge and capacity were built through a training programme held in September 2006.

These trainings on crab fattening includes topics on water quality management, species identification, culture and fattening, feed management, and tank maintenance both

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[2] *Source:* "Crab Fattening: Alternative Livelihood for Fisherwomen", M S Swaminathan Research Foundation, December 2009

theoretically and practically. The number of members of SHGs was reduced to 10 when the activity took off later. Initially the group was given five cages for every 15 days' cycle and all the cages were maintained by the group as a whole. The number of cages was later increased to 10.

Technical components related to the soil and water conditions, atmospheric temperature, stocking details, feed details, duration of fattening, harvesting and handling of the crabs while transporting were discussed in the training programme. The women participants in the programme wanted to grow small crabs and sell them at higher price during the season as the availability of the crabs is seasonal.

Initiation and implementation of crab fattening

A number of field visits were undertaken to understand the needs of the local communities in designing programmes. Prioritisation support was extended by MSSRF depending upon the need. Implementing agency was formed at the village level. An MoU was signed between the foundation and the local community based groups regarding the roles, responsibilities, monitoring mechanisms, and sharing of resources and benefits. Activities in the field were facilitated to help the community in participation and ownership in the rehabilitation process. Field staff of the Foundation monitored the functioning of SHGs rather than actively participating.

The process of crab fattening

The cage culture method of crab fattening was adopted in Tamil Nadu. Cages are kept immersed in water tied with bamboo poles for support. The cages are made of fibre glass consisting of nine chambers, costing around Rs 5000 each procured from the Periyar Integrated Fish Farm. It is durable and portable and the crabs cannot bite the hard plastic material. The water crabs are released into the chambers and since then 20 to 30 days on an average are required to fatten the water crabs. Stocking density is one per each inner segment. Survival rate is 90 per cent. Cycle per year is eight. Mud crab juveniles are stocked individually in each chamber. This is to ensure that the losses due to cannibalism can be ignored. After the crabs have been harvested, the hardened crabs would be sold at the rate of Rs 250 per kg in the market, which had been procured at the rate of Rs 100 per kg. These mud crabs are omnivorous (eating both animal and plant food) as they feed on a wide variety of food items. Forty per cent of the total cost of the production goes into the feed.

Harvesting of the hard crabs is done from the 10th day onwards and up to 30 days. The average increase in weight after fattening is around 40–50 g. Harvested crabs are immediately placed in a moist and shady, cool place. Thereafter the crabs are packed and transported to dealers. While transporting the crabs either after purchase for fattening or taking them to the market, these crabs cannot survive high temperature. So the women always wrapped perforated bags with wet cloth to maintain cool climate, thus reducing the mortality rate due to the heat outside. Peak season, when the crabs are available for fattening, is between July and November every year. Crab availability decreases drastically during the lean season in this region. As a result, the cost of procuring soft crabs escalates almost three-fourths of its original cost in lean season. Fish and dry fish vending is done during this season.

Economic benefits of crab fattening

SHGs in Tamil Nadu have earned a profit of Rs 80,480 from fattening crabs in the two years 2008–09 and 2009–10. In 2009–10, they fattened 250 crabs worth Rs 75,000. Each woman member earned a profit of Rs 700–1000 per month when all the cages were stocked to its full capacity. This has helped and encouraged Malligai SHG to apply for similar loan to expand their crab fattening enterprise in April 2008. Turnover in such activities is fast as the period between the investment and returns is relatively short.

4.2.5 Economic Analysis of Crab Fattening

NIOT Initiative in Andaman and Nicobar Islands, 2004–05

We would like to examine how an initiative from NIOT affects the production and profitability at the individual fishermen's level in the Islands. Results presented in this section are based on a study by NIOT based on the crab fattening activities in 2004–05 in Andaman and Nicobar Islands. The economics of crab fattening in one crop (cycle) in Andaman and Nicobar Islands is described in Table 4.4

- The expenditure on total operation including that on water crab and feed was 40.7 per cent of the total income.
- Capital invested for the pond was Rs 5,000 for one year with proper care and maintenance.
- One crop / cycle could be completed within 30–35 days. Six crops could be achieved in one year.
- Assuming that the land is owned by the farmer, only depreciation on the construction material (fixed cost for six crops) was calculated as 16.6 per cent, which amounted to Rs 833.
- Total deduction on the total income was Rs 6,433 which included operational and depreciation cost of pond per crop.
- After all the deductions, the net income was Rs 8,147 for each crop in one pond with an area of 300 sq m.

Table 4.4.: Economics of Mud Crab Fattening (30–35 Days) in One Pond (Area: 300 m2): by NIOT in 2004

Expenditure/Income	Amount (Rs)
Capital investment: Pond preparation including excavation, bund building, bamboo fencing, etc.	5,000
Operational expenditure	
Water crab – 60 kg @ Rs 70 per kg	4,200
Feed purchase – 70 kg trash fish and clam meat @ Rs 20 per kg	1,400
Total operational expenditure	5,600
Gross income – 54 kg @ 85 per cent survival and sold @ Rs 270 per kg	14,580
Deductions	
Operational cost	5,600
16.6 per cent of capital investment (depreciation)	833
Total deductions from gross income	6,433
Net profit	
Gross income – total deductions	8,147

Source: http://moeseprints.incois.gov.in/523/1/O14._fatting_of__mud.pdf

MSSRF Initiative in Tamil Nadu, 2007–08 and 2008–09

Next, we would like to examine how an initiative was taken by MSSRF in Tamil Nadu in 2008–09. The detailed economics of crab fattening activity implemented by MSSRF in 2008–09 and 2007–08 is presented in Table 4.5. It is interesting to note that the net profit from crab fattening has jumped almost by three folds from 2007–08 to 2008–09 which infers improvement in the efficiency of the process.

Table 4.5: Economics of the Crab Fattening in One Cycle during 2008–09: MSSRF

Economics of the Crab Fattening	
Description	**Amount (Rs)**
Purchase of 71.6 kg water crabs for 10 cages @ Rs 100 per kg	7,160
Feed cost of 50 kg trash fish @ Rs 20 per kg	1,000
Sale of 67.5 kg p. good crab @ Rs 250 per kg	16,875
Wage @ Rs 50/ 2 hrs per day for 25 days	1,250
Total income	16,875
Operation cost (purchase cost + feed cost + labour cost)	9,410
Net profit per cycle	7,465
Total for eight cycles	59,720
2007–08	
Purchase of 35.8 kg water crabs for all the 5 cages @ Rs 100 per kg	3,580
Feed cost of 25 kg trash fish @ Rs 20 per kg	500
Sale of 31.7 kg p. good crab @ Rs 250 per kg	7,925
Wage @ Rs 50 / 2 hrs per day for 25 days	1,250
Total income	7,925
Operation cost (Purchase cost + Feed cost + labour cost)	5,330
Net profit per cycle	2,595
Total for eight cycles	20,760

Source: http://www.mssrf.org/ecotech/ebook/et-pub-08.pdf

4.2.6 Socio-economic Impact of Crab Fattening: Primary Field Survey in Andaman and Nicobar Islands

As part of the present study, NCAER conducted a primary field survey in a few villages in Andaman and Nicobar Islands, where training on crab fattening was provided by NIOT during September to December 2004. The villages surveyed included Stewart Gunj, Krishna Nagar, Vijay Nagar, Sholbay, Shore Point, Wimberly Gunj, Radha Nagar and Laxmipur. The prime objective of the study was to assess the perception of household population regarding benefits of crab fattening and its impact of the economy of the fishermen community.

Coverage of Primary Field Survey

The target group for the quantitative survey comprised those who underwent training provided by NIOT on crab fattening in these villages. In total a sample of 34 households (one chief wage earner per household) were surveyed as part of this field study. Semi-structured questionnaires were used to collect the required information from people trained in lobster culture / fattening.

Training on Crab Fattening by NIOT

Most of the people (98%) were aware of crab fattening even before the NIOT intervention. The survey also attempted to understand the various aspects covered during the training provided on crab fattening or converting juvenile crabs into market crabs. It was found that different aspects of the training ranged from ways of earning better income and improving economic conditions through crab fattening, methods of juvenile crab cultivation, and ways of exporting juvenile crab seeds overseas.

Of the total population who received training from NIOT, 75 per cent felt that the training was beneficial to them since they learnt the actual process of crab fattening and related technical issues. Those respondents who reported receiving training were further asked whether the training helped in getting better price for crabs. However, most of them could not provide any information since they have not been able to commercially take up crab fattening activity after receiving the training. Because of Tsunami in December 2004, all the people who received training lost their cages used for crab fattening. None of them have been able start the process again because of the very high initial costs involved.

Profitability of Crab Fattening Activity

During the survey, some important facts came to light which shows that crab fattening can indeed prove to be a profitable business opportunity for the fishermen. However, since all the information provided by the people was based on their experiences during the period before December 2004. Some of the key figures recollected by the population are mentioned below.

- The surveyed population reported that the cost of each cage used for crab fattening was about Rs 1700 in 2003.
- It was learnt that majority of the families were undertaking four cycles in a year and the number of cages used per cycle ranged from 100 to 150.
- Mostly greenish variety of crab is used for fattening process as these are the most profitable and each cage contained two juvenile crabs, one male and one female.
- The juvenile crabs weighed around 200–250 g before fattening, which were priced at around Rs 30 to Rs 80 per kg.
- After fattening the weight of crabs becomes 1000–1100 g, which were priced at Rs 450 to 500 per kg.

As of April 2012, the fattened crabs in the surveyed island fetch a price of around Rs 1100 per kg, while their market price before fattening is only around Rs 450–500 per kg. These data show that the market for crab fattening is huge.

Potential of Crab Fattening in the Andaman Islands

The survey revealed that there is huge potential for crab fattening, which is still left untapped because of financial issues. After the Tsunami of 2004, most of the people have stopped crab fattening altogether because of lack of capital to resume the activity. As can be learnt from the field survey, the return on investments in fattening process is considerably high. However, because of the very high capital involved, not many have been able to scale up this initiative to a commercial venture. Moreover, the surveyed population reported that the cages are difficult to maintain and they do not have adequate expertise required for crab fattening activity.

Therefore, even though crab fattening has great potential in these coastal areas, it will be successful only when people receive some initial support and handholding either by the government or non-governmental organisations at least for a few years initially. Support is required in terms of setting up of cages that involve minimum maintenance costs, and arranging seeds and feed for the juvenile crabs. The fishermen have expressed the desire that either NIOT or any similar kind of institute should provide new training and updates on the crab fattening technology.

4.2.7 Concluding Remarks

In Andaman and Nicobar Islands the potential for crab fattening exists. Prior to the Tsunami in December 2004, the islands had adopted the NIOT developed crab fattening activity. Inhabitants are eager that such an activity be re-initiated. *The activity was abandoned post-2004 Tsunami. Islanders expressed the need for an intervention by NGOs to provide necessary support in technology adoption as well as in accessing funds.*

In 2006, MSSRF adopted an initiative with the objective of providing income-earning opportunities and fostering sustainable livelihood security of the fishing communities, agriculture farmers, widowed women, and orphaned children affected badly by the Tsunami. It is a micro-credit programme through SHGs for the fishing communities to revive and diversify the livelihoods[3].

If NIOT enters into a MoA with MSSRF to re-initiate the activity in Andaman and Nicobar islands and replicate it in calm seas elsewhere along India's sea-coast, wide-scale adoption of NIOT developed practices is feasible in India. Such an agreement can be a win-win game for both the organisations.

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[3] *Source:* "Crab Fattening, Alternative Livelihood for Fisherwomen", M.S. Swaminathan Research Foundation, December 2009

Marine Ornamental Fish Hatching in Lakshadweep Islands

Chapter 5
Ornamental Fish Culture

5.1 Introduction

Keeping ornamental fish in an aquarium is one of the most popular hobbies in the world today. The growing interest in aquarium fishes has resulted in steady increase in ornamental fish trade globally. More than 50 per cent of the ornamental fish supply to the world originates in Asia. Of this, around 80 per cent is farm-raised fresh water fish, 15 per cent is marine-based, and 5 per cent is fresh water species. The largest exporter of ornamental fish is Singapore followed by Hong Kong, Malaysia, Thailand, Philippines, Sri Lanka, Taiwan, Indonesia, and India. Singapore specialises in farming fresh water species. The global export market of ornamental fish was estimated to be worth around six billion dollars in 2010. The biggest importer of ornamental fishes is the USA followed by Europe and Japan. Over US $ 500 million worth of ornamental fish are imported into the USA each year. The other emerging markets are China and South Africa. Feasibility of hatching marine ornamental fish in the backyard hatcheries of coral islands for export market and the impact of such hatching practices on the Islands' economy is the main issue analysed in this chapter.

Seas, fresh water, and the brackish water bodies abound the Indian sub-continent with attractive varieties of fishes, which are popular across many countries. Despite the huge potential offered by the rich diversity and environment, export of ornamental fish from India continues to remain negligible. Export of marine ornamental fish is yet to fully take off from India. India's share in global ornamental fish trade is only 0.01 per cent. At the same time, there is a very good domestic market for ornamental fish in India, which is growing at a significant pace. The domestic market is mainly based on domestically-bred exotic species. The present domestic market is estimated to have crossed Rs 10 crore and is growing at a rate of 20 per cent annually.

5.1.1 Marine Ornamental Fishing

Marine ornamental fish culture is at a very nascent stage at present in India. Marine fishes are caught wild in the seas. However, if these species are directly exported after their wild collection, then they tend to exhibit very high mortality rates. In order to export them to other countries or to transport them within the country, they need to be cultured and developed up to a certain stage. At the same time breeding or rearing of marine ornamental fishes in hatcheries is equally important in order to sustain long-term export growth. In other words an application of marine biology principles and practices in hatching developed by CMLRE is the central theme examined in this section.

Organised trade in ornamental fish depends on assured and adequate supply of demand, which is possible only by mass breeding. CMLRE, under the Ministry of Earth Sciences, is working towards the goal in the coral islands of Lakshadweep. The process of wild collection of ornamental fish and farming in hatcheries is being developed by CMLRE in the Agatti Island of Lakshadweep. Presently, the process is in the initial stage. This is an application of marine biology to create livelihood generating opportunity for the community in the islands.

Coral islands such as Lakshadweep have major potential for ornamental fish culture because of the availability of good water as per the required composition.

5.1.2 CMLRE and Hatching of Ornamental Fish in Agatti Island's Backyard Hatcheries

The present study focuses on culture of marine ornamental fish in coral islands. As a livelihood generating activity, it has great earning potential for inhabitants of coral islands in India, besides contributing to India's exports. However, this potential has yet not been exploited fully in a technology driven manner. The main objective of this chapter is to study and analyse the economic impact of hatching marine ornamental fish culture in the coral islands, as an additional source of household income generation. A field survey was conducted to assess how the relevant technology, being provided by CMLRE in Agatti Island of Lakshadweep, has helped in adapting ornamental fish culture as a livelihood-generating activity for the people involved. The survey also aims to understand the usefulness of training and technology provision, and economic benefits from this activity.

It is learnt from the survey that the islanders received training on various aspects such as ornamental fish breeding and rearing, information on species suited particularly for ornamental fishing, space availability for rearing and breeding, fish specific catchment areas, risk prone areas, and marketing opportunities. A significant proportion of respondents believe that the training has been helpful since they gained knowledge about the technical aspect of ornamental fish farming. However, it has been revealed during the survey that ornamental fish farming has not commercially taken off after they received the training as the process is capital intensive.

The rest of the chapter has been structured hereafter as under:

- Evidence of marine ornamental fish culture in Lakshadweep: A CMLRE initiative
- Economic analysis of marine ornamental fish culture: Evidence from primary field survey

5.2 Evidence of Marine Ornamental Fish Culture in Lakshadweep: A CMLRE Initiative

In this section, we focus our discussion on a specific case where ornamental fish culture has been adopted by people of the Islands as an additional source of income generation. The initiative under discussion has been started in Agatti Island of Lakshadweep by CMLRE. It deals with the breeding and rearing of marine ornamental fish in hatcheries, an application of marine biology. Along with the discussion on technology details and related activities involved, we also present an economic impact analysis for this initiative in the next chapter.

The CMLRE Initiative

CMLRE, under the Ministry of Earth Sciences (MoES), started a field research station at Agatti Island in 2010 to develop hatchery technologies for marine ornamental fishes to help Lakshadweep islanders by providing additional source of income, without disturbing the fragile island ecosystem. One of the objectives of this initiative was to provide technology for breeding and rearing of ornamental fishes at CMLRE hatchery unit of Lakshadweep and its commercialisation. Ornamental fish trade, an expanding multi-million-dollar industry, relies almost exclusively on the collection of these animals from coral reef ecosystems, where they thrive. And the collection of these organisms is done extensively in Indian waters, which has raised concerns of irreversible damage to the entire reef ecosystem and depletion of the target species. The project aims to standardise the hatchery technology of commercially important ornamental fishes, undertake stock enhancement and sea ranching of commercially in-demand and threatened species, train the local communities, set up backyard hatchery units for islanders for income generation and promote the market potential and trade of ornamental fishes. CMLRE has selected this specific location for this initiative because good sea-water is available to grow the ornamental fishes, which is a pre-requisite in marine-based culture. Also, the initiative has huge potential for income generation for the fishermen community in the island, which can make it economically viable. Presently, the main sources of income for the islanders include coconut, tourism, shipping and certain other primary activities (explained in detail in next section).

Provision of training by CMLRE

Twenty young people were selected based on educational qualifications for providing training related to use of hatchery technology being developed by CMLRE for ornamental fishing culture. CMLRE was initially looking for young people having a Masters degree as participants. However, since they could not find sufficient number of young individuals with such education level, the criteria was reduced to 10th/12th standard. An amount of Rs 2000 per month was paid as incentive to the trainees. The training was given during January to May 2011.

Building and Development of Hatchery

The trainees did not have their own hatchery. Therefore, CMLRE rented land from local people in the island and built their hatchery. The trainees have been using CMLRE's hatchery for culture of ornamental fishes. On an average, the cost of building a hatchery is around Rs 3 lakh. The broad break-up of investment cost is provided in Table 5.1.

Table 5.1: Investment Cost of CMLRE per Hatchery at 2010-11 prices

Cost component	Amount (Rs)
Cost of 20 tanks (@ Rs 10, 000 per tank) 14 tanks are required in one cycle while six tanks are back up	2,00,000
Cost of water filtration	25,000
Cost of pumps (2)	10,000
Total investment cost	**3,00,000** (approx.)

Source: CMLRE

CMLRE grows the seeds in their laboratory through induced breeding. Then they provide the 3-week old seeds to fishermen who then grow them from juvenile to the marketable size, i.e. from three weeks to three months. CMLRE also provides technical support for the maintenance of the fish larvae and juveniles in the backyard hatcheries, feeding and packing of the fully grown juveniles.

Economic impact

The objective of CMLRE is to provide research and development services (R&D), so that the islanders can have a long-term source of income. Presently, CMLRE does not even charge for the seeds. To be specific, CMLRE tries to provide ornamental fishing technology to the islanders as it is energy efficient to grow them. Eventually, it is expected that the business would be profitable enough and can be practiced in the islands.

In o`rder to make the CMLRE initiative on marine ornamental fish culture financially viable, the fishermen have to buy 6,000 seeds, which they can divide and keep in two different tanks at the beginning. On the 5th week, the number of tanks required is four, while in the third month, it increases to eight. The survival rate is generally found to be 80 per cent even if the best care is provided. A very broad analysis of income that could be generated by fishermen by taking up marine ornamental fish culture under these conditions is provided in Table 5.2.

Table 5.2: Income Generated from Each Cycle of CMLRE Initiative at 2010-11 prices

Item	Amount (Rs)
Selling price per 3-month old fish	70 to 75
Total income for 4800 fishes (6,000 minus 20 per cent mortality)	3,36,000 to, say 3,50,000
Cost of feed (charged by CMLRE)	75,000
Profit per hatchery	2,75,000
Profit per head per month (in a group of 4 people)	**65,000 (approx.)**

Source: CMLRE

It is difficult to find wholesale traders in Agatti Island. In this case, the Tata group is the trader. They buy the fishes at the three-month stage and sell it in Singapore at the rate of Rs 120 to Rs 140 per fish to cover additional transportation and logistics costs, mortality risks of ornamental fish during transit as well as profits while local fishermen sell it to a Tata firm at Rs 70 per fish.

5.3 Socio-economic Impact of Marine Ornamental Fish Culture: Evidence from Primary Field Survey in Lakshadweep

As part of the present study, NCAER conducted a primary field survey in Agatti Island, where training on ornamental fishing was provided by CMLRE. The prime objective of the study was to assess the perception of people regarding benefits of ornamental fishing. The survey also aims to understand the usefulness of training and technology provision and economic benefits from this activity.

Coverage of Primary Field Survey

The target group for the quantitative survey comprised of those who underwent training provided by CMLRE on ornamental fishing in Agatti Island. In total a sample of 18 households were surveyed as part of this field study. Semi structured questionnaires were used to collect the required information from people trained in ornamental fishing.

Socio-economic Profile of Study Population

This section presents the demographic and socio-economic profile of the sample population.

A. Age distribution

A considerable proportion (59%) of the sample population is in the 21–30 age group. Thirty five per cent of the respondents belong to the 31–40 age group while 6per cent are from the 41–50 age group. The average age of the sample population was found to be 29 years.

B. Marital status

More than two-fifths of the sample population were married.

C. Religion and Caste
All the respondents covered under the study were Muslims. Almost half of the respondents were Scheduled Tribes while the rest belonged to Other Backward Classes (OBCs).

D. Educational attainment
Around half of the sample population was found to have attained education up to higher secondary level. About 17 per cent of the respondents were found to be graduates.

E. Occupation
A significant proportion of the sample population (23%) is skilled workers, while 17 per cent are unskilled workers. The major occupations include fishing (11%), clerical jobs (11%), and private sector jobs (6%). Eleven per cent of the respondents were home makers.

F. Family income
The average monthly household income of the sample households is observed to be approximately Rs 11000. Approximately 22 per cent people earn less than Rs 5000 per month. Around 33 per cent of the households reported that their household income is in the range of Rs 5,000–10,000 and Rs 10001–15000, respectively. Eleven per cent respondents reported that their monthly income was more than Rs 15,000.

Training on Ornamental Fishing from CMLRE
The sample population was asked whether they were aware of the ornamental fishing before the CMLRE intervention. Most of the people (72%) replied in the affirmative while 23 per cent reported no awareness regarding the same. The respondents were further asked whether they got any training on ornamental fishing. About 78 per cent respondents replied in the positive. Sixty six per cent among them conveyed that the training was provided by CMLRE while 11per cent informed that it was provided by department of fisheries. They received training for three months starting February 2011. It was further extended up to September 2011.

They received training on various aspects such as ornamental fish breeding and rearing, information on species suited particularly for ornamental fishing, space availability for rearing and breeding, fish specific catchment areas, risk prone areas, favourable areas for fishing, suitable weather for fishing, and marketing and export opportunities. A significant proportion of respondents (78%) believe that the training has been helpful since they gained knowledge about ornamental fish farming. Eighty five per cent of the study population considers this training helpful as it taught them the technical aspect of ornamental fish farming. According to CMLRE officials, the trainees were provided Rs 2000 per month as incentive to participate in the training. When asked, 61 per cent answered that they received the incentive.

Support from Local Groups and Institutions
An important aspect of the field survey was to collect information on whether local NGOs / SHGs operating in their area provided information about technological process of hatchery. It is interesting to note that 56 per cent respondents agreed about the positive role of local NGOs in this regard. Those who reported that local NGOs / SHGs were operational for

providing information were further probed about the kind of information which was provided. The responses range from "breeding conditions for fishes", "species suited particularly for ornamental fishing", "fish rearing", and "market prices for ornamental fishes", etc.

Regarding participation of the community or community level institutions, it was reported by Panchayat members and CMLRE that Panchayats are willing to take ownership of the hatchery unit. The unit had, in fact, been developed with funds from CMLRE and the Panchayats. Ever since it was set up, the process of ornamental fishing has been carried out by CMLRE only on an experimental basis. Now even though the Panchayats are willing to take ownership of the hatchery units, there are a few internal issues which need to be sorted out.

Up-scaling of Ornamental Fishing
All the surveyed individuals were enquired whether they were continuing the process of hatchery based ornamental fishing. It has been revealed during the survey that ornamental fish farming has not commercially taken off after they received the training. This is mostly because setting up of hatcheries is expensive and, therefore, they need financial help in hatchery process.

However, 22 per cent of the sample population reported that as part of tourism, they pooled money and purchased an aquarium in which they had ornamental fish. This was then set up as a museum. An amount of Rs 30–50 used to be charged from foreign tourists while it was Rs 10 for Indians. However, it is not operating at present since tourism is closed for the time being.

Formation of co-operatives would be beneficial to expand the ornamental fishing activities in the households. The respondents were asked whether they would like to introduce some more families into their ornamental fishing co-operative. All of them agreed. Twenty eight per cent of them further reported to involve around 10 families within the co-operative.

5.4. Concluding Remarks

Marine ornamental fishing is an interesting marine biology application in the context of Lakshadweep Islands that can increase the fishing households' income and the islands' gross domestic product without disturbing the marine eco-system.

The need of the hour is to scale up the project from an experimental 14 members' initiative to the full Island's initiative. Roughly 150 fishing families in Agatti and around 200 fishing families in Kavaratti can set up the back-yard hatcheries to augment their family income. Scaling up of the activities by CMLRE can be accomplished in two ways:

1. Recognising the need to develop the project in public/private sector mode on commercial lines and recognising that both CMLRE as well as the Ministry of Earth Sciences would need a separate legal entity for domiciling all the assets (mainly tanks) and the cash flows of the project for the purpose of securitisation and to fulfil the need of having a focused management of the project, may be CMLRE needs to set up an SPV.

This would have a separate legal entity for entering into specific contracts, agreements with the panchayats, with the private sector, etc.

2. The alternative approach would be the simple option of forming an SHG in each island and authorising them, collectively, to receive funds from CMLRE or seek the state administration's intervention as has been successfully done in introduction of LTTD technology for drinking water supply in these islands.

In fact, the choice of LTTD desalination technology and the initiation of marine ornamental fishing hatcheries complement each other. Thus the economic benefits of developing ornamental fishing hatcheries as well as the introduction of LTTD technology need to be analysed in an integrated fashion. Similarly their joint impact on the economies of Agatti and Kavaratti Islands is to be computed. This has been attempted in Chapter 6.

Impact of Desalination and Ornamental Fishing Activities on Island Economies of Lakshadweep, Agatti, and Kavaratti

Chapter 6

Estimates of GSDP, Employment, and Input–Output Tables for Lakshadweep as a Whole, and Agatti and Kavaratti Islands Separately

Input–output (I–O) models are used to calculate the direct and indirect impact of an increased demand of a particular commodity by consumers on the total output of the economy.

We had shown in the earlier section that the Low Temperature Thermal Desalination (LTTD) technology evolved by NIOT is an ideal example of a stand-alone technology that does not disturb the existing eco-system of the coral islands of Kavaratti and Agatti. Similarly the introduction of the concept of "back yard hatcheries" in coral islands to hatch "ornamental fish", through an application of marine biology for export markets can help fisheries-based-households realise better incomes without disturbing the existing ecosystem.

The crucial task for policy planners is to estimate the possible direct and indirect impact of the introduction of LTTD technology as well as "backyard hatcheries" based ornamental fishing on the "domestic product" and "employment" in Kavaratti and Agatti. The evolution of I–O models for Agatti and Kavaratti Islands is the approach adopted in this study to estimate the direct and indirect impacts of MoES programmes in coral islands.

NIOT, under MoES, has set up two LTTD plants – one in Kavaratti (operational) and the other at Agatti (installed in 2012) each with a capital investment (total fixed capital and working capital requirements) of Rs 1751.71 lakh (exclusive of the interest capitalised for the construction period). Similarly, CMLRE, under MoES, is attempting to introduce the concept of backyard hatcheries to enable fisheries-based households export ornamental fish. An NCAER survey estimates that roughly 200 households in Kavaratti and 150 in Agatti are willing to adopt the concept. The object of this exercise is to estimate the likely impact of introduction of LTTD capital investments and the annual expenditures to operate the desalination plants as well as the increased income of households realised through exports of ornamental fish on the economies of Agatti, Kavaratti, and Lakshadweep Islands at the end of the gestation period.

In other words, in the following section we use available data to measure the additional direct and indirect impacts due to these activities, and the resultant effect on the gross domestic product (GDP) and employment of Lakshadweep Islands, at the end of the gestation periods for the projects. Similar analysis has also been carried out for Agatti and Kavaratti Islands.

6.1 Gross State Domestic Product

The gross state domestic product (GSDP) for Lakshadweep has been estimated for 2009–10 using the available data on the production of agriculture, livestock, forestry and fishing, expenditure details from the budget documents, labour force, population, and information collected from the Directorate of Economics and Statistics, Lakshadweep Administration.

The GSDP estimates of Lakshadweep have further been disaggregated for the islands of Agatti and Kavaratti. These estimates are presented in Table 6.1 below.

Table 6.1: Estimates of GSDP for Lakshadweep, Agatti and Kavaratti, 2009–10

		GSDP, 2009–10 (Rs lakh)		
Sl No.	Industry	Lakshadweep	Agatti	Kavaratti
1	Agriculture	5519	938	993
2	Forestry and logging	286	34	50
3	Fishing	3697	1183	758
4	Mining			
5	Manufacturing	247	30	37
6	Construction	4356	2831	915
7	Electricity	1514	152	339
8	Water supply	81	9	14
9	Railways			
10	Transport and storage	6294	2295	1285
11	Communication	858	75	87
12	Trade	1028	391	203
13	Hotels and restaurants	160	53	31
14	Banking and insurance	1019	374	209
15	Real estate and dwellings	2307	271	401
16	Public administration	17890	894	12523
17	Other services	3475	417	1042
Total GSDP		**48729**	**9947**	**18887**
Population		64645	7450	11000
Per capita income		**75380**	**133522**	**171702**

Source: Author's calculations NCAER, 2012

6.1.1 Input–output Tables

In order to assess the linkages between industries and to facilitate impact analysis of induced final demand, input–output (I–O) Tables for 2009–10 have been constructed for Lakshadweep, Agatti and Kavaratti, based on the above GSDP estimates and the I–O coefficients available from the all-India input–output transactions tables compiled by CSO.

I–O Tables for the three regions are presented below:

Table 6.2: I–O Table for Lakshadweep, 2009–10 (Rs lakh)

	Commodity X Commodity	1	2	3	4	5	Inter-industry use	Final demand	Output at factor cost
1	Agriculture, livestock and forestry	1625	0	431	0	495	2551	6077	8628
2	Fishing	0	161	4	0	2	166	4179	4346
3	Mining, manufacturing, electricity, construction	489	349	7357	14	6396	14605	2972	17577
4	Water supply	1	0	25	12	10	47	94	141
5	Services	858	143	3625	33	6222	10881	35325	46206
Gross input at factor cost		**2973**	**652**	**11442**	**59**	**13125**	**28250**	**48647**	**76898**
Net indirect taxes		-95	-4	-24	1	41	-81	281	199
Gross input at market prices		2878	649	11417	60	13165	28169	48928	77097
Gross value added at factor cost		**5750**	**3697**	**6160**	**81**	**33041**	**48729**		
Gross output at factor cost		**8628**	**4346**	**17577**	**141**	**46206**	**76898**		

Source: Author's calculations NCAER, 2012

Every row in Table 6.2 lists the quantities of output of the corresponding industry that all the listed industries in the economy of Lakshadweep, respectively demand as intermediate inputs for the production of their outputs. It also shows the demand for that industry's output for final consumption. Each column shows an industry's purchase of inputs from other industries (and itself), as also the value added by it.

The same information is then translated to yield the Leontief Inverse (Table 6.3), wherein the column totals yield output multipliers, that is the multiple by which the total output in Lakshadweep increases for a unit increase in the final demand of a particular sector's output on account of desalination and ornamental fishing activities.

Table 6.3: Leontief Inverse for Lakshadweep, 2009–10

		1	2	3	4	5
1	Agriculture, livestock and forestry	1.2394	0.0060	0.0612	0.0134	0.0251
2	Fishing	0.0000	1.0385	0.0004	0.0001	0.0001
3	Mining, manufacturing, electricity, construction	0.1641	0.1627	1.8322	0.2802	0.2952
4	Water supply	0.0004	0.0003	0.0029	1.0934	0.0007
5	Services	0.1817	0.0791	0.4445	0.3622	1.2291
Output multipliers		**1.5856**	**1.2864**	**2.3413**	**1.7492**	**1.5502**

Source: Author's calculations NCAER, 2012

Similarly, I–O Tables and corresponding Leontief Inverses are computed for Agatti and Kavaratti Islands as shown in Tables 6.4 to 6.7.

Table 6.4: I–O Table for Agatti, 2009–10 (Rs lakh)

	Commodity X Commodity	1	2	3	4	5	Inter-industry use	Final demand	Output at factor cost
1	Agriculture, livestock and forestry	276	0	210	0	73	559	886	1445
2	Fishing	0	52	2	0	0	55	1336	1391
3	Mining, manufacturing, electricity, construction	100	136	4426	2	1132	5797	2836	8633
4	Water supply	0	0	12	1	1	15	1	16
5	Services	122	20	978	3	693	1817	4863	6680
Gross input at factor cost		**498**	**209**	**5629**	**7**	**1900**	**8242**	**9922**	**18165**
Net indirect taxes		−16	−1	−13	0	6	−25	14	−11
Gross input at market prices		482	208	5615	7	1905	8217	9936	18154
Gross value added at factor cost		**963**	**1183**	**3018**	**9**	**4775**	**9947**		
Gross output at factor cost		**1445**	**1391**	**8633**	**16**	**6680**	**18165**		

Source: Author's calculations NCAER, 2012

Table 6.5: Leontief Inverse for Agatti, 2009–10

		1	2	3	4	5
1	Agriculture, livestock and forestry	1.2447	0.0074	0.0688	0.0160	0.0281
2	Fishing	0.0001	1.0392	0.0005	0.0001	0.0001
3	Mining, manufacturing, electricity, construction	0.2284	0.2262	2.1606	0.3899	0.4114
4	Water supply	0.0005	0.0004	0.0034	1.0935	0.0009
5	Services	0.1464	0.0461	0.2804	0.3068	1.1707
Output multipliers		**1.6199**	**1.3194**	**2.5136**	**1.8063**	**1.6113**

Source: Author's calculations NCAER, 2012

Table 6.6: I–O Table for Kavaratti, 2009–10 (Rs lakh)

	Commodity X Commodity	1	2	3	4	5	Inter-industry use	Final demand	Output at factor cost
1	Agriculture, livestock and forestry	339	0	105	0	274	719	832	1551
2	Fishing	0	34	1	0	1	35	855	891
3	Mining, manufacturing, electricity, construction	104	85	1842	3	3624	5657	-1951	3706
4	Water supply	0	0	5	2	5	12	12	24
5	Services	93	15	463	5	2374	2951	19120	22071
Gross input at factor cost		537	134	2415	10	6278	9374	18868	28242
Net indirect taxes		-20	-1	-7	0	9	-19	300	281
Gross input at market prices		517	133	2408	10	6287	9355	19168	28523
Gross value added at factor cost		1033	758	1298	14	15784	18887		
Gross output at factor cost		1551	891	3706	24	22071	28242		

Source: Author's calculations NCAER, 2012

Table 6.7: Leontief Inverse for Kavaratti, 2009–10

		1	2	3	4	5
1	Agriculture, livestock and forestry	1.2898	0.0086	0.0809	0.0186	0.0328
2	Fishing	0.0001	1.0394	0.0005	0.0001	0.0001
3	Mining, manufacturing, electricity, construction	0.2105	0.2144	2.0972	0.3696	0.3889
4	Water supply	0.0004	0.0003	0.0033	1.0935	0.0009
5	Services	0.1166	0.0507	0.2996	0.3156	1.1774
Output multipliers		1.6174	1.3133	2.4814	1.7974	1.6001

Source: Author's calculations NCAER, 2012

6.1.2 Activities for Which Impact Analysis is Carried Out

A. LTTD

The activities of LTTD plants are classified under the industry classification of water supply. Since no charges are levied for the supply of water, this activity is treated as non-market activity of the government and accordingly the output of the activity is estimated on cost basis (i.e. sum of total costs). From the details available in respect of these plants, the following estimates of economic aggregates have been made:

Table 6.8: Estimates of Gross Output and Gross Value Added on Account of LTTD Activity

Gross output =	Compensation of employees (personnel expenses) + consumption of fixed capital (depreciation) + intermediate consumption (operating expenses)	=18.35+135.64+40.90 = Rs 194.89 lakh
Gross value added =	Gross output – intermediate consumption	= 194.89 – 40.90 = Rs 153.99 lakh

Source: Author's calculations NCAER, 2012
Note: Same values for both Agatti and Kavaratti Island

B. Ornamental Fish Trade

The activity of ornamental fish trade falls under the fishing industry. This is carried out by government and the fishermen (households). Subsequently, ornamental fish is exported through a trader, whose activities fall under trading. Based on the available information, the estimates of economic aggregates are given in Table 6.9.

Table 6.9: Estimates of Gross Output and Gross Value Added on Account of Ornamental Fish Trade

Aggregate	Government (fishing activity)	Households (fishing activity)	Exporter (trading activity)
Agatti			
Gross output	18.384 (CoE) + 0.10 (elec) + 0.25 (other operating expenses) + (4.50/25) (depreciation) = Rs 18.91 lakh	13.4*150 (Receipts) = Rs 2010 lakh	Rs 603 lakh (assuming 30 per cent margin)
Gross value added	18.91 – 0.35 = Rs 18.56 lakh	2010–450 = Rs 1560 lakh	Rs 302 lakh, (assuming 50 per cent operating expenses)
Kavaratti			
Gross output	18.384 (CoE) + 0.10 (elec) + 0.25 (other operating expenses) + (4.50/25) (depreciation) = Rs 18.91 lakh	13.4*200 (Receipts) = Rs 2680 lakh	Rs 804 lakh (assuming 30 per cent margin)
Gross value added	18.91 – 0.35 = Rs 18.56 lakh	2680–600 = Rs 2080 lakh	Rs 402 lakh, (assuming 50 per cent operating expenses)

Source: Author's calculations NCAER, 2012

6.1.3 Impact of LTTD and Ornamental Fish Trade on the Economy

The gross output estimated on account of LTTD and ornamental fishing activities is indicated in Tables 6.8 and 6.9. This is the direct impact on the economy of Agatti and Kavaratti Islands and is purely on account of the additional activities of LTTD and ornamental fishing. However, the increasing demand for LTTD and ornamental fishing activities will require additional output from other industries too so that they provide the additional output to LTTD and ornamental fishing activities to meet the additional demand for these products.

For estimating the indirect impact, the static Leontief model (based on Leontief inverse) is used. The estimated direct and indirect impacts on account of LTTD and ornamental fishing activities in Lakshadweep, Agatti and Kavaratti are shown in Tables 6.10 to 6.12.

Table 6.10: Estimates of Final Demand and Gross Output on Account of LTTD and Ornamental Fishing (Rs lakh) – Lakshadweep

		Present estimates		Additional gross output (direct and indirect) due to LTTD and ornamental fishing		Total gross output (direct and indirect) due to LTTD and ornamental fishing		Percentage increase in	
		Final demand	Gross output	Final demand	Gross output	Total final demand	Gross output	Final demand	Gross output
1	Agriculture, livestock and forestry	6077	8628	0	69	6077	8697	0.0	0.8
2	Fishing	4179	4346	4728	4910	8907	9256	113.1	113.0
3	Mining, manufacturing, electricity, construction	2972	17577	0	1294	2972	18871	0.0	7.4
4	Water supply	94	141	390	429	484	570	415.2	304.4
5	Services	35325	46206	1407	2244	36732	48450	4.0	4.9
Total at factor cost		**48647**	**76898**	**6525**	**8945**	**55172**	**85843**	**13.4**	**11.6**

Source: Author's calculations NCAER, 2012

For Lakshadweep as a whole, the activity of LTTD will generate an additional demand of Rs 390 lakh and accordingly the direct impact on output of Lakshadweep will be Rs 390 lakh. However, due to this activity, there will be an additional indirect impact of Rs 39 lakh.

For ornamental fishing the direct impact will be of Rs 4728 lakh and indirect impact of Rs 182 lakh. In fishing the direct impact is of Rs 1407 lakh in services sector and indirect impact of Rs 837 lakh. The overall output of Lakshadweep due to these two activities will go up by 11.6 per cent.

Table 6.11: Estimates of Final Demand and Gross Output on Account of LTTD and Ornamental Fishing (Rs lakh) – Agatti

		Present estimates		Additional gross output (direct and indirect) due to LTTD and ornamental fishing		Total gross output (direct and indirect) due to LTTD and ornamental fishing		Percentage increase in	
		Final demand	Gross output	Final demand	Gross output	Total Final demand	Gross output	Final demand	Gross output
1	Agriculture, livestock and forestry	886	1445	0	35	886	1480	0.0	2.4
2	Fishing	1336	1391	2029	2109	3365	3499	151.9	151.6
3	Mining, manufacturing, electricity, construction	2836	8633	0	783	2836	9416	0.0	9.1
4	Water supply	1	16	195	215	196	231	15904.6	1321.7
5	Services	4863	6680	603	859	5466	7539	12.4	12.9
Total at factor cost		**9922**	**18165**	**2827**	**4001**	**12749**	**22165**	**28.5**	**22.0**

Source: Author's calculations NCAER, 2012

For Agatti, the activity of LTTD will generate an additional demand of Rs 195 lakh and accordingly the direct impact on output of Lakshadweep will be Rs 195 lakh. However, due to this activity, there will be an additional indirect impact of Rs 20 lakh in the economy.

For ornamental fishing, the direct impact will be of Rs 2029 lakh and indirect impact of Rs 80 lakh. In fishing the direct impact is of Rs 603 lakh in services and indirect impact of Rs 256 lakh. The overall output of Agatti due to these two activities will go up by 22 per cent.

Table 6.12: Estimates of Final Demand and Gross Output on Account of LTTD and Ornamental Fishing (Rs lakh) – Kavaratti

		Present estimates		Additional gross output (direct and indirect) due to LTTD and ornamental fishing		Total gross output (direct and indirect) due to LTTD and ornamental fishing		Percentage increase in	
		Final demand	Gross output	Final demand	Gross output	Total final demand	Gross output	Final demand	Gross output
1	Agriculture, livestock and forestry	832	1551	0	53	832	1604	0.0	3.4
2	Fishing	855	891	2699	2805	3554	3696	315.5	314.9
3	Mining, manufacturing, electricity, construction	−1951	3706	0	963	−1951	4669	0.0	26.0
4	Water supply	12	24	195	215	207	239	1627.1	896.6
5	Services	19120	22071	804	1145	19924	23216	4.2	5.2
Total at factor cost		**18868**	**28242**	**3698**	**5182**	**22566**	**33424**	**19.6**	**18.3**

Source: Author's calculations NCAER, 2012

For Kavaratti, the activity of LTTD will generate an additional demand of Rs 195 lakh and accordingly the direct impact on output of Kavaratti will be Rs 195 lakh. However, due to this activity, there will be an additional indirect impact of Rs 20 lakh in the Kavaratti economy.

For the ornamental fishing activity, the direct impact will be of Rs 2699 lakh and indirect impact of Rs 106 lakh. In fishing direct impact is of Rs 804 lakh in services sector and indirect impact of Rs 341 lakh. The overall output of Kavaratti due to these two activities will go up by 18.3 per cent.

6.2 Total Employment

The latest estimates of employment in Lakshadweep are available from the 66th round survey on employment and unemployment conducted in 2009–10 by the National Sample Survey Organisation (NSSO). By analysing the unit level data of the 66th round and suitably adjusting for multiple jobs and under-count in population numbers in this survey, the estimates of employment in terms of jobs have been compiled. According to these, the total employment in terms of jobs in Lakshadweep during 2009–10 was 35,744.

However, employment data for the islands of Agatti and Kavaratti are not separately available from NSS 66th round. The latest island-wise employment numbers available for Lakshadweep was from the Population Census of 2001. This data, however, is not available by industry. In order to estimate employment numbers by activities and for the islands of Agatti and Kavaratti, the ratios available from (i) population census, 2001 on island-wise employment, and (ii) employment to GDP ratio of Lakshadweep have been used. The steps involved in the estimation are given below:

(a) Total employment for Agatti and Kavaratti for 2009–10 has been estimated using the share of employment in these two islands to the total employment in Lakshadweep from the Population Census, 2001. This gives the total employment in Agatti as 4288 and in Kavaratti as 7936 for the year 2009–10.
(b) Industry-wise employment for Agatti and Kavaratti has been estimated using the corresponding ratios of employment to GSDP for Lakshadweep.
(c) The estimated industry-wise employment obtained through step (b) is further adjusted to the control figures of employment available from step (a), to arrive at the final figures of employment by industry in Agatti and Kavaratti for the year 2009–10.

The results of the compilations are shown in Table 6.13.

Table 6.13: Estimates of Employment in Lakshadweep, Agatti and Kavaratti Islands by Industry

	Industry	2009–10 – Employment (jobs) (no.)		
		Lakshadweep	Agatti	Kavaratti
1	Agriculture	9405	838	1355
2	Forestry and logging	0	0	0
3	Fishing	5888	987	966
4	Manufacturing	3774	237	453
5	Construction	3236	1102	544
6	Electricity	446	23	80
7	Water supply	48	15	19
8	Transport by other means	2651	510	435
9	Storage	0	0	0
10	Communication	282	13	23
11	Trade	686	137	109
12	Hotels and restaurants	409	71	63
13	Banking and insurance	90	17	15
14	Real estate and dwellings	223	14	31
15	Public administration	5560	134	3107
16	Other services	3045	191	731
	Total	**35744**	**4288**	**7936**

Source: Census of India

The above table has been summarised into five broad important sectors of Lakshadweep in Table 6.14.

Table 6.14: Estimates of GDP and Employment in Lakshadweep, Agatti and Kavaratti by Industry

	Sectors	2009–10 – GDP (Rs lakh)			2009–10 – Employment (jobs) (no.)		
		Lakshadweep	Agatti	Kavaratti	Lakshadweep	Agatti	Kavaratti
1	Agriculture, livestock and forestry	5,805	972	1,043	9,405	837	1,357
2	Fishing	3,697	1,183	758	5,888	987	967
3	Mining, manufacturing, electricity, construction	6,116	3,013	1,291	7,457	1,362	1,078
4	Water supply	81	9	14	48	15	19
5	Services	33,030	4,771	15,782	12,946	1,087	4,515
	Total	48,729	9,947	18,888	35,744	4,288	7,936

Source: Census of India

6.2.1 Input–Output Tables of Employment

In order to assess the linkages between industries and to facilitate impact analysis of induced final demand, I–O Tables for 2009–10 on employment have been constructed for Lakshadweep, Agatti and Kavaratti, based on the above employment estimates and the I–O Tables previously compiled on domestic production of industries for these three islands. The I–O Tables on employment for the three regions are presented in Tables 6.15 to 6.20.

Table 6.15: I–O Table on Employment for Lakshadweep, 2009–10 (no.)

	Commodity X Commodity	Agriculture, livestock and forestry	Fishing	Mining, manufacturing, electricity, construction	Water supply	Services	Inter-industry use	Final demand	Total employment
1	Agriculture, livestock and forestry	1755	0	465	0	534	2754	6561	9316
2	Fishing	0	218	5	0	3	225	5663	5888
3	Mining, manufacturing, electricity, construction	209	149	3152	6	2740	6257	1273	7530
4	Water supply	0	0	8	4	3	16	32	48
5	Services	241	40	1017	9	1745	3052	9910	12962
	Total intermediate use	2205	407	4647	19	5026	12305	23439	35744
	Total employment	9316	5888	7530	48	12962	35744		

Source: Author's calculations NCAER, 2012

Table 6.16: Leontief Inverse on Employment for Lakshadweep, 2009–10

Sector		Agriculture, livestock and forestry	Fishing	Mining, manufacturing, electricity, construction	Water supply	Services
1	Agriculture, livestock and forestry	1.2394	0.0047	0.1543	0.0424	0.0967
2	Fishing	0.0001	1.0385	0.0013	0.0003	0.0006
3	Mining, manufacturing, electricity, construction	0.0651	0.0514	1.8322	0.3531	0.4508
4	Water supply	0.0001	0.0001	0.0023	1.0934	0.0009
5	Services	0.0472	0.0164	0.2911	0.2990	1.2291
Multipliers for increase in employment in final demand		1.3519	1.1111	2.2812	1.7881	1.7780

Source: Author's calculations NCAER, 2012

Table 6.17: I–O Table on Employment for Agatti, 2009–10 (no.)

Commodity X Commodity		Agriculture, livestock and forestry	Fishing	Mining, manufacturing, electricity, construction	Water supply	Services	Inter-industry use	Final demand	Total employment
1	Agriculture, livestock and forestry	158	0	121	0	42	321	509	830
2	Fishing	0	37	1	0	0	39	948	987
3	Mining, manufacturing, electricity, construction	16	22	702	0	179	919	449	1368
4	Water supply	0	0	11	1	1	14	1	15
5	Services	20	3	159	1	113	296	793	1089
Total intermediate use		194	62	994	2	336	1588	2700	4288
Total employment		830	987	1368	15	1089	4288		

Source: Author's calculations NCAER, 2012

Table 6.18: Leontief Inverse on Employment for Agatti, 2009–10

		1	2	3	4	5
1	Agriculture, livestock and forestry	1.2447	0.0060	0.2493	0.0101	0.0990
2	Fishing	0.0001	1.0392	0.0022	0.0001	0.0006
3	Mining, manufacturing, electricity, construction	0.0630	0.0505	2.1606	0.0678	0.4001
4	Water supply	0.0008	0.0005	0.0194	1.0935	0.0051
5	Services	0.0416	0.0106	0.2883	0.0549	1.1707
Multipliers for increase in employment in final demand		**1.3501**	**1.1068**	**2.7198**	**1.2264**	**1.6755**

Source: Author's calculations NCAER, 2012

Table 6.19: I–O Table on Employment for Kavaratti, 2009–10 (no.)

	Commodity X Commodity	Agriculture, livestock and forestry	Fishing	Mining, manufacturing, electricity, construction	Water supply	Services	Inter-industry use	Final demand	Total employment
1	Agriculture, livestock and forestry	294	0	91	0	238	623	721	1344
2	Fishing	0	37	1	0	1	38	929	967
3	Mining, manufacturing, electricity, construction	31	25	541	1	1065	1662	-573	1089
4	Water supply	0	0	4	2	4	9	9	19
5	Services	19	3	95	1	486	604	3913	4517
Total intermediate use		344	65	732	0	1793	2937	4999	7936
Total employment		1344	967	1089	19	4517	7936		

Source: Author's calculations NCAER, 2012

Table 6.20: Leontief Inverse on Employment for Kavaratti, 2009–10

	Commodity X Commodity	Agriculture, livestock and forestry	Fishing	Mining, manufacturing, electricity, construction	Water supply	Services
1	Agriculture, livestock and forestry	1.2898	0.0069	0.2387	0.0207	0.1391
2	Fishing	0.0001	1.0394	0.0018	0.0001	0.0007
3	Mining, manufacturing, electricity, construction	0.0714	0.0580	2.0972	0.1397	0.5583
4	Water supply	0.0004	0.0002	0.0087	1.0935	0.0033
5	Services	0.0275	0.0096	0.2087	0.0831	1.1774
Output multipliers		1.3891	1.1140	2.5550	1.3371	1.8787

Source: Author's calculations NCAER, 2012

6.2.2 Activities for which Impact Analysis on Employment has been Carried out

A. LTTD

The activities of LTTD plants come under the industry classification of water supply. According to the information available, there are 12 persons employed in this activity in each of Agatti and Kavaratti Islands. No additional employment is envisaged.

B. Ornamental fishing

The activity of ornamental fishing falls under fishing industry. This is carried out by government and the fishermen (households). Subsequently, ornamental fishes are exported through a trader, whose activities fall under trading. Based on the available information, the estimates of additional employment due to this activity are given in Table 6.21.

Table 6.21: Estimates of Additional Employment on Account of Ornamental Fishing (no.)

Aggregate	Government (fishing activity)	Households (fishing activity)	Exporter (trading activity)
Agatti			
Employment	Currently, five government employees are working. No additional employment is envisaged.	150 households will take up this activity and 600 persons are expected to be employed.	About 17 persons are expected to be employed.
Kavaratti			
Employment	Currently, five government employees are working. No additional employment is envisaged.	200 households will take up this activity and 800 persons are expected to be employed.	About 23 persons are expected to be employed.

Source: Author's calculations NCAER, 2012

6.2.3 Impact of LTTD and Ornamental Fishing on Employment in the Islands

The additional employment estimated on account of LTTD and ornamental fishing activities has been indicated above. This is 1400 in the case of ornamental fishing and 40 for trading in Lakshadweep. The break-up is 600 for Agatti and 800 for Kavaratti in respect of ornamental fishing and 17 for Agatti and 23 for Kavaratti in the case of trading. This is the direct impact on the employment of Agatti and Kavaratti Islands and is purely on account of additional activities of LTTD and ornamental fishing. However, the increasing demand for employment in LTTD and ornamental fishing will generate additional employment in other industries too so that they provide the requisite support to LTTD and ornamental fishing activities to enable them to meet the additional labour demand in these activities.

For estimating the indirect impact, the static Leontief model (based on Leontief inverse) has been used. The estimated direct and indirect impacts on account of LTTD and ornamental fishing activities in Lakshadweep, Agatti and Kavaratti are shown in Tables 6.22 to 6.24.

Table 6.22: Estimates of Increase in Employment on Account of LTTD and Ornamental Fishing – Lakshadweep

Sector		Present employment estimates (No.)		Additional employment (direct and indirect) due to LTTD and ornamental fishing (No.)		Estimated total employment after LTTD and ornamental fishing (no.)	Percentage increase in employment
		Employed to meet final demand	Total employ-ment	Direct employ-ment	Direct and indirect employ-ment		
1	Agriculture, livestock and forestry	6561	9316	0	11	9326	0.1
2	Fishing	5663	5888	1400	1454	7342	24.7
3	Mining, manufacturing, electricity, construction	1273	7530	0	90	7620	1.2
4	Water supply	32	48	0	0	48	0.3
5	Services	9910	12962	40	72	13034	0.6
Total		23439	35744	1440	1627	37370	4.6

Source: Author's calculations NCAER, 2012

For Lakshadweep as a whole, for the activities of LTTD and ornamental fishing, the direct impact on employment will be 1440 and on indirect employment will be 187. The overall increase in employment in Lakshadweep due to these two activities will be 4.6 per cent.

Table 6.23: Estimates of Increase in Employment on Account of LTTD and Ornamental Fishing – Agatti

Sector		Present employment estimates (no.)		Additional employment (direct and indirect) due to LTTD and ornamental fishing (no.)		Estimated total employment after LTTD and ornamental fishing (no.)	Percentage increase in employment
		Employed to meet Final demand	Total employ-ment	Direct employ-ment	Direct and indirect employ-ment		
1	Agriculture, livestock and forestry	509	830	0	5	835	0.6
2	Fishing	948	987	600	624	1610	63.2
3	Mining, manufacturing, electricity, construction	449	1368	0	37	1405	2.7
4	Water supply	1	15	0	0	15	2.4
5	Services	793	1089	17	26	1115	2.4
Total		2700	4288	617	693	4981	16.2

Source: Author's calculations NCAER, 2012

For Agatti for the activities of LTTD and ornamental fishing the direct impact on employment will be 617 and indirect impact will be 76. The overall increase in employment of Lakshadweep due to these two activities will be 16.2 per cent.

Table 6.24: Estimates of Increase in Employment on Account of LTTD and Ornamental Fishing – Kavaratti

	Sector	Present employment estimates (no.)		Additional employment (direct and indirect) due to LTTD and ornamental fishing (no.)		Estimated Total employment after LTTD and ornamental fishing (no.)	Percentage increase in employment
		Employed to meet final demand	Total employ-ment	Direct employ-ment	Direct and indirect employ-ment		
1	Agriculture, livestock and forestry	721	1344	0	9	1353	0.6
2	Fishing	929	967	800	832	1799	86.0
3	Mining, manufacturing, electricity, construction	−573	1089	0	59	1148	5.4
4	Water supply	9	19	0	0	19	1.5
5	Services	3913	4517	23	35	4552	0.8
Total		4999	7936	823	934	8871	11.8

Source: Author's calculations NCAER, 2012

For Kavaratti for the activities of LTTD and ornamental fishing, the direct impact on employment will be 823 and indirect impact will be 111. The overall increase in employment of Lakshadweep due to these two activities will be 11.8 per cent.

Summary

The impact of LTTD plants and adoption of ornamental fishing activities on the Islands' domestic product and employment of Agatti, Kavaratti, and Lakshadweep can be summarised as in Table 6.25.

Table 6.25: Summary Table

	Agatti Island	Kavaratti Island	Lakshwadeep Islands
Percentage increase in final demand	28.5	19.6	13.4
Percentage increase in gross output at factor cost	22	18.3	11.6
Percentage increase in islands gross domestic product	22	18.3	11.6
Percentage increase in islands employment	16.2	11.8	4.6

Source: Author's calculations NCAER, 2012

In other words, the MoES programmes of introduction of LTTD technology as well as backyard hatcheries to export ornamental fish can result, after the gestation period, in an increase of Lakshdweep's domestic product by 12 per cent. The increase in the domestic product of Agatti and Kavaratti would be around 22 per cent and 18 per cent, respectively. Similarly, total employment in Lakshadweep would increase by 5 per cent, and that for Agatti and Kavaratti by 16 per cent and 12 per cent, respectively.

References

References

"Costing of desalinated water from sea using low temperature thermal desalination technology in islands (Lakshadweep)", August 2010, Vinod K. Agarwal and Co., Chartered Accountants, New Delhi.

"Low Temperature Thermal Desalination Applications for Drinking Water", National Institute of Ocean Technology, Ministry of Earth Sciences, Velachery Tambaram Main Road, Narayanapuram, Chennai.

"Standing Committee on Rural Development (2009–2010)", Ministry of Rural Development (Department of Drinking Water Supply), Demands for Grants (2010–2011), Eight Reports.

von Medeazza, G. M. "Desalination in Chennai: What About the Poor and the Environment? 2006. Economic and Political Weekly.

Karagiannis I.C and Soldatos P.G. "Water Desalination Cost Literature: Review and Assessment. 2007. *Desalination Journal*, available online at www.sciencedirect.com.

Mezher .T, Fath H, Abbas Z., Khaled A. "Techno-economic Assessment and Environmental Impacts of Desalination Technologies". 2010. *Desalination Journal*, available online at www.sciencedirect.com

"Farming of Spiny Lobsters in Sea Cages in India", *New Zealand Journal of Marine and Freshwater Research*, Volume 43, Issue 2, 2009

"Status of Major Lobster Fisheries in India", The Royal Society of New Zealand, 2005.

Vijayakumaran, M and Radhakrishnan, E V. "Lobster Culture and Live Transport" in *Proceedings of the Workshop National Aquaculture Week*, Central Marine Fisheries Research Institute, Kochi, 1998.

Kadalekum Kanivukal (Bounties of the Sea), Farm School Series on Marine Fisheries Broadcast by All India Radio, Thrissur, edited By K. Ravindran, Krishna Srinath, K.K. Kunjipalu, V. Sasikumar, Central Institute of Fisheries Technology, Matsyapuri P.O., Kochi and All India Radio, Ramavarmapuram, Thrissur.

"Management of Spiny Lobsters Fishery Resources", National Biodiversity Authority, 2006.

"Lobster Farming in India", E.V. Radhakrishnan, Artificial Reefs and Seafarming Technologies, Central Marine Fisheries Research Institute, Indian Council of Agricultural Research, Kochi, 1996.

Earth System Science Organization, Ministry of Earth Sciences, Draft Approach Paper for the 12th Five Year Plan (2012–2017).

Indian Journal of Geo-Marine Sciences, Volume 40, Number 1, February 2011, editorial "Ornamental Fish Industry".

Central Institute of Freshwater Aquaculture, Bhubaneshwar, Orissa (http://www.cifa.in/)

Centre for Marine Living Resources and Ecology

Nabard's Model Bankable Projects, Ornamental Fish Breeding (http://www.nabard.org/modelbankprojects/fish_ornamental_fish.asp).