# *STOCHASTIC MODELS IN FISHERY ECONOMICS WITH SPECIAL REFERENCE TO KERALA*

G.RAJAGOPALAN UNNITHAN

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**DOCTOR OF PHILOSOPHY**

APRIL 1999

DEDICATED TO MEMORY OF MY BELOVED
PARENTS

# CERTIFICATE

This is to certify that this Thesis entitled **Stochastic Models in Fishery Economics with Special Reference to Kerala** submitted to the University of Calicut for the award of **Degree of Doctor of Philosophy in Statistics** is a record of original research work done by G. Rajagopalan Unnithan during the period of his study in the Department of Statistics, University of Calicut, Kerala, under my supervision and guidance and the Thesis has not formed the basis for award of any Degree/Diploma/Associateship/Fellowship or similar title to any candidate of any University or Institute.

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# DECLARATION

I hereby declare that the matter embodied in this Thesis is the result of investigations carried out by me in the Department of Statistics, University of Calicut, under the supervision and guidance of Dr. K. Kumaran Kutty, Retd. Professor and Head, Department of Statistics, University of Calicut and it has not been submitted for award of any Degree/Diploma/Associateship/Fellowship of any other University or Institute.

27/4/99

CANDIDATE

SUPERVISOR

27-4-99

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# CONTENTS

# INTRODUCTION

G. Rajagopalan Unnithan "Stochastic models in fishery economics with special reference to Kerala " Thesis. Department of Statistics , University of Calicut, 1999

# INTRODUCTION

# INTRODUCTION

With limited land resources available for agriculture, a few large industrial establishments and the highest density of population in the country, it is but natural that the state of Kerala leans very much on its water resources - especially the marine resource - for food, employment and sustainable economic growth.

Fisheries sector has turned out to be one of the core industrial sectors contributing significantly to the state's domestic product over the years. Kerala ranks first among the states in terms of marine landings in the country with an estimated production of 5,72,000 tonnes in 1996, accounting for 23.62 percent of the all India marine landings. Contribution of Kerala to the foreign exchange earnings from marine products also is very substantial, amounting to over 900 crores rupees in the same year. In a state where the pace of industrial growth has been rather slow compared to many of its neighbours owing to many economic and social reasons, fisheries sector has been instrumental in providing both direct and indirect employment to a considerably large percentage of the people. These achievements are all the more spectacular when we consider the fact that the major beneficiaries of this sector have been the rural coastal folks.

Against this background, it is essential to evolve suitable fishery management policies for sustained development of the marine fisheries. The inter-relations between income from fisheries sector and the net state domestic product of the state over time are to be understood. The fish catch trends are to be observed for getting an insight into the behaviour of the system. Estimates of the maximum sustainable yield and the optimum fishing efforts are to be regularly updated. Variations in both fishery dependent and independent factors and their impact on the fishery are to be clearly examined. Trend in the export of marine products is to be analysed. The present study aims at enhancing our understanding of the fisheries in Kerala by the application of suitable stochastic models. The marine fisheries system and its behaviour over time is analysed in this study by the application of stochastic models. Scope of this work is limited to the marine fisheries sector in Kerala. Attempts are made to develop new models and to validate existing models which have practical applications.

An efficient marketing system controls the distribution of fish and fishery products both for internal and international markets. Thus marine fisheries plays a significant role in the overall economic development of the state of Kerala by contributing substantially to its viable economic growth.

Marine fishery economy is a dynamic system which is related to time factor. Manifestations of this system at different time points can better be understood by studying the interdependency of various explanatory variables. In fact, the study of any chronological developments (data) is very basic to fishery economic analysis for which models can be used as most handy and efficient tools. The inter-relations of different variables help us to formulate models of various economic phenomena like production, income etc.

A basic view of scientific modelling is that a model is a simplified description of a system in a mathematical language which may be used as a means of forecasting. Models are ways of viewing a system, its problems and future prospects. In fact, the prime reason for modelling is to provide us means of enhancing our understanding about the system and guide us in decision making. The applicability of models to practical situations may be tested from deducing certain verifiable statistics from the model and testing them with actual data. The value of any model depends on how far it incorporates those features of the real situation.

Pindyck, R.S. and Rubinfeld, D.L. (1991) observed that the science of model building consists of a set of quantitative tools, which are used to construct and then test mathematical representation of the real world.

However, there is no hard and fast rule for choosing or formulating any particular type of model. In many cases, application of a particular model largely depends on intuitive judgements and one's past experience. An adequate insight into the relationship between the variable is most essential for the construction of a model which is subjected to a statistical testing. Such explicitly constructed models provide a high measure of reliability to the models.

Main objectives of the present study are to :

(i) Study the contribution of fisheries sector to the economy of Kerala using time series and regression models.

(ii) Investigate the trends in the marine fish production over years employing Logistic, Gompertz, Bass and other suitable models.

(iii) Assess the marine fishery resource for optimum exploitation of prawn species by using Schaefers', Fox, Hyperbolic and Power models.

(iv) Study the effect of environmental parameters on fishery using appropriate models.

(v) Study the trend in the marine product exports from Kerala employing ARIMA models for short term forecasting.

State domestic product is an important economic indicator which has been divided into primary, secondary and tertiary sectors. Growth of the state domestic product, fishing industry and primary sector over the years is analysed using time series models. Effect of marine and inland catches on income from fishing industry is discussed with the help of regression models. Forecasting of income from fishing industry also is attempted. Per capita output, per capita income etc. Are investigated using appropriate models. These are the main contents of the first chapter.

In the second chapter, trends in the fish landings are studied using suitable growth models. Logistic, Gompertz, Malthus, Exponential and Bass models provided good fit to the data. All models used to study the growth in fish landings are non-linear in nature.

Using the catch and effort statistics, synthetic models have been applied to update the maximum sustainable catch and optimum level of fishing efforts for the conservation of the fishery resources, in the third chapter. Schaefer and Fox models are applied apart from Hyperbolic and Power models. Economics of Operation of fishing trawlers are also investigated.

Fishery independent factors like rainfall, temperature, humidity etc. play an important role in the fish catch. The effect of environmental factors on fish landing is presented in Chapter four using appropriate models.

Chapter five deals with the application of ARIMA models in the trend analysis of the marine products exports from Kerala. Time series data of frozen prawns, total export etc. are modelled. Exports to international markets like USA and Japan also are probed.

The study is mainly concentrated on the application of suitable stochastic models in fisheries, particularly in the area of marine fisheries. The models envisaged in this study are expected to help the researchers, planners and policy makers for ensuring a viable fisheries sector in Kerala.

## Reference


Alagaraja, K., (1984) Simple methods for estimation of parameters for assessing exploited fish stocks. *Indian J. Fish.* **31**, 177-208.

Barlett, M. S. (1960). *Stochastic Population Models in Ecology and Epidemiology*. Methuen and Company Ltd., London.

Draper, N.R. and Smith, H. (1981). *Applied Regression Analysis*. John Wiley, New York.

Fox, W.W. Jr. (1970). An exponential surplus yield model for optimising exploited fish populations. *Trans. Am. Fish. Soc.* **99**(1), 80-88.

Hanumara, R.C. and Hoenig, N. (1987). An empirical comparison of a fit of linear and non-linear models for seasonal growth in fish. *Fish. Res.* **5**, 359-381.

Pankratz, A. (1983). *Forecasting with Univariate Box – Jenkins Models*. 562p. John Wiley & Sons. Inc. New York.

Pauly, D. (1980). On the interrelationship between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *J. Cons. Ciem.* **39**(2), 175-192.

Pawlac, C. and Hanumara, R.C. (1991). A comparison of non-linear growth models for fisheries. *Fish. Res.* **11**, 143-154.

Pindyck, R.S. and Rubinfeld, R.L. (1991). *Econometric Models and Economic Forecasts* (3rd Edn.) MCGRAW-HILL, INC. New York.

Saila, S.B., Wigbout, M. and Lermit R.J. (1980). Cinoarusib if sine time series models for analysis of fisheries data. *J. Cons. Ciem.* **39**, 44-52.

# FISHERIES SECTOR AND THE ECONOMY OF KERALA -AN OVERVIEW

G. Rajagopalan Unnithan "Stochastic models in fishery economics with special reference to Kerala " Thesis. Department of Statistics , University of Calicut, 1999

# CHAPTER I

# CHAPTER I

# FISHERIES SECTOR AND THE ECONOMY OF KERALA - AN OVERVIEW

## 1.0 Introduction

State Domestic Product (SDP) and Percapita Income (PI) etc. are important indicators of a State's economy. State Domestic Product is the total contribution generated by all that are produced within the state. The Net State Domestic Product (NSDP) at factor cost is divided by industry of origin into three major sectors, viz. primary, secondary and tertiary (Anon, 1994; 1995). Fishing industry belongs to the Primary sector in which Agriculture, Forestry and Logging, Mining and Quarrying form the other constituents.

The Primary Sector (PS) had played a dominant role in the economy of Kerala since the formation of the State in 1956. The share of the PS was 55.98 percent in 1960-61, followed by the Tertiary sector with 28.79 percent and the Secondary sector with 15.23 percent (constant prices). Fishing industry was only at a dormant state contributing 1.96 percent to the Primary sector and 1.10 percent to the NSDP. Fishing industry's share amounted to rupees 475 lakhs only against rupees 24196 lakhs of the PS and rupees 43222 lakhs of the NSDP during 1960-61 (base 1960-61). At the current price level also, the share of the fishing industry was only 1.96 percent of the PS (Anon, 1961).

Now, after 35 years, the economic scenario has undergone drastic changes with the fishing industry contributing rupees 10010 lakhs and the Primary Sector, rupees 208873 lakhs and the NSDP reaching the level of rupees 646104 lakhs (Constant levels) (base:1980-81) during 1994-95.The population of the state has gone up from 1.67 crores to over 3.05 crores during this period.

Against this background, an attempt is made in this chapter to evaluate the impact of the fishing industry over time on the primary sector and on the economy of the state as a whole by the use of appropriate stochastic models.

## 1.1 Materials and methods

The data on income from different sources to the state domestic product, the other economic indicators like per capita income, production, population etc. published annually by the state planning board and state fisheries department, Government of Kerala, form the main data base for this study.

Models employed in this chapter are basically regression models. As given by Draper and Smith (1981), regression model with a singleindependentvariable X is of the form

$$Y = \beta_0 + \beta_1 X + \varepsilon \quad \text{------------} \quad (1.1.1)$$

Where Y is the dependent variable, $\beta_0$, $\beta_1$ are constants to be evaluated by the method of least squares and $\varepsilon$ is the error term. For n sets of observations $(X_i, Y_i)$, $i = 1, \ldots, n$

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i \text{ ------------------------- } (1.1.2)$$

Sum of squares of deviations from the true line is

$$S = \sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n} (Y_i - \beta_0 - \beta_1 X_i)^2 \text{ ------------------------- } (1.1.3)$$

If values $b_o$ and $b_1$ are estimates of $\beta_0$ and $\beta_1$ such that S is minimum,, then

solving the normal equations give

$$b_o n + b_1 \sum_{i=1}^{n} X_i = \sum_{i=1}^{n} Y_i \text{ and}$$

$$b_o \sum_{i=1}^{n} X_i + b_1 \sum_{i=1}^{n} X_i^2 = \sum_{i=1}^{n} X_i Y_i \text{ ------------------------- } (1.1.4)$$

we get the value of $b_1$ such that

$b_1 = S_{XY} / S_{XX}$ where

$S_{XY} = \sum X_i Y_i - n \bar{X} \bar{Y}$ and $S_{XX} = \Sigma X_i^2 - n \bar{X}^2$

substituting the value of $b_1$ in equation $b_0 = \bar{Y} - b_1 \bar{X}$ ---(1.1.5)

the value of $b_0$ is obtained. Significance of $b_0$ and $b_1$ are tested against their respective standard errors. Precision of the regression line may be obtained from the relation,

$$\Sigma(Y_i - \bar{Y})^2 = \sum(\hat{Y}_i - \bar{Y})^2 + \sum(Y_i - \hat{Y}_i)^2 \text{ ------------------------- } (1.1.6)$$

where the 1st term is the sum of squares about the mean, 2nd term is sum of squares due to regression and the last term is the sum of squares about the regression. From (1.1.6) we can construct an analysis of variance table as below:

Table 1.1 : ANOVA

| Source of variation | Degrees of freedom | sum of squares (SS) | Mean square (MS) |
|---|---|---|---|
| Due to regression | 1 | $\sum(\hat{Y}_i - \bar{Y})^2$ | ss/df |
| Due to residual | n-2 | $\sum(Y_i - \hat{Y}_i)^2$ | ss/df |
| Total | n-1 | $\Sigma(Y_i - \bar{Y})^2$ | |

Basic assumptions of the regression model are

(i) $\varepsilon_i$ is a random variable with mean zero and variance $\sigma^2$.

(ii) $\varepsilon_i$ and $\varepsilon_j$ are independent and

(iii) $\varepsilon_i$ is normally distributed.

The F test for significance of regression is given by

F = MS due to regression / MS due to residual variation

$R^2$ is the measure of the total variance explained by the regression and is given by

$R^2$ = SS due to regression / Total SS

## 1.2 Growth of Fishing Industry, Primary Sector and NSDP

The economy of Kerala registered an impressive growth during the five year period ending 1995. The contribution of fishing industry increased from rupees 5,457 lakhs in 1989-90 to rupees 10,010 lakhs in 1994-1995 at constant prices. For the Primary Sector, the corresponding figures were 1,64,496 lakhs and 2,08,873 lakhs, whereas the Net State Domestic Product registered an increase from 4,89,236 lakhs to 6,46,104 lakhs (Table 1.2) during this period. Thus increase in the FI, PS and NSDP were 83 percent, 27 and 32 percent respectively during this period.

At constant price levels fishing industry contributed 4.0 to 5.0 percentage to the Primary Sector and about 2.0 percentage to the Net State Domestic Product.

**Table 1.2 : *Net Domestic Product at Factor Cost**
(At constant prices) (NEW SERIES)
Base Year : 1980-81, (Figs. Rs. Lakhs)

| Year | Fishing Industry | Primary Sector | Net State Domestic Product | Population '000 | Per Capita Income (Rs) |
|---|---|---|---|---|---|
| 1980-81 | 7743 | 149970 | 382273 | 25357 | 1508 |
| 1981-82 | 5797 | 144153 | 377481 | 25699 | 1469 |
| 1982-83 | 6958 | 144909 | 386851 | 26046 | 1485 |
| 1983-84 | 7691 | 131900 | 371168 | 26398 | 1406 |
| 1984-85 | 6764 | 144028 | 394158 | 26754 | 1473 |
| 1985-86 | 7042 | 149969 | 408636 | 27115 | 1507 |
| 1986-87 | 5917 | 141902 | 399297 | 27481 | 1453 |
| 1987-88 | 4592 | 144790 | 416563 | 28114 | 1482 |
| 1988-89 | 6505 | 167731 | 458410 | 28402 | 1614 |
| 1989-90 | 5457 | 164496 | 489236 | 28693 | 1705 |
| 1990-91 | 9380 | 189386 | 526234 | 28987 | 1815 |
| 1991-92 | 8847 | 195427 | 536466 | 29378 | 1826 |
| 1992-93 | 9138 | 196550 | 575161 | 29775 | 1932 |
| 1993-94 | 9694 | 208526 | 616459 | 30177 | 2043 |
| 1994-95 | 10010 | 208873 | 646104 | 30584 | 2113 |

*Ref: Economic Review - 1994, Appendix 2.2
Economic Review - 1995
Govt. of Kerala, Sate Planning Board, Thiruvananthapuram.

During 1980-85 period, the contribution of fishing industry to the Primary Sector was 4.90 percent, which declined to 3.85 percent during 1985-90 and improved to 4.72 percent in 1990-95.

Table 1.3 gives the contribution of different sectors at current prices.

**Table 1.3 : *Net Domestic Product at Factor Cost**
(At current prices) (NEW SERIES)
Base Year : 1980-81, (Figs. Rs. Lakhs)

| Year | Fishing Industry | Primary Sector | Net State Domestic Product | Population '000 | Per Capita Income (Rs) |
|---|---|---|---|---|---|
| 1980-81 | 7743 | 149970 | 382273 | 25357 | 1508 |
| 1981-82 | 6292 | 146143 | 404973 | 25699 | 1576 |
| 1982-83 | 7923 | 176867 | 471150 | 26046 | 1809 |
| 1983-84 | 8938 | 217048 | 552328 | 26398 | 2092 |
| 1984-85 | 8942 | 233312 | 614145 | 26754 | 2296 |
| 1985-86 | 11777 | 225251 | 650341 | 27115 | 2398 |
| 1986-87 | 12104 | 257643 | 735437 | 27481 | 2676 |
| 1987-88 | 10661 | 280675 | 825756 | 28114 | 2937 |
| 1988-89 | 16845 | 311013 | 918172 | 28402 | 3233 |
| 1989-90 | 28370 | 349121 | 1066768 | 28693 | 3718 |
| 1990-91 | 37193 | 400601 | 1217349 | 28987 | 4200 |
| 1991-92 | 50685 | 594074 | 1510165 | 29378 | 5140 |
| 1992-93 | 56049 | 618795 | 1717520 | 29775 | 5768 |
| 1993-94 | 56789 | 627455 | 1883667 | 30177 | 6242 |
| 1994-95 | 58067 | 702479 | 2135795 | 30584 | 6983 |

*Ref: Economic Review - 1994, Appendix 2.2
Economic Review - 1995
Govt. of Kerala, Sate Planning Board, Thiruvananthapuram.

Considering the growth of each sectors over the 15 years commencing from 1980, it is noted that the NSDP (constant prices).

grows by larger absolute amounts than the fishing sector and the primary sector. To investigate the over all proportionate increase, we consider $FI_{95} / FI_{80}$, where $FI_{95}$ and $FI_{80}$ correspond to the values for the years 1995 and 1980 respectively. This proportion is 1.29. Similarly for PS and NSDP, the corresponding figures are 1.39 and 1.69 respectively.

In other words, over the fifteen years, Fishing Industry, primary sector and the NSDP increased by 29 percent, 39 percent and 69 percent respectively. Thus the rate of growth of the fishing sector was not commensurate with that of the primary sector and NSDP, and infact, the lowest.

### 1.3 Growth of FI, PS and NSDP

Apart from quantitative contribution of each sector, the general pattern of growth also is of great significance. This will clearly indicate how the fishing sector and the economy have developed over the years. The sequential characteristics of the economic variables in the study will be clearly brought out and the pattern can give an indication of how the variables will behave in future.

Thus models were fitted to economic variables such as income from fishing industry, primary sector and the Net State Domestic Product (constant prices, base year : 1980-81).

Assuming them as increasing functions over time, linear models were tried first, to get growth trend.

The fitted models were as follows.:

1. $Y = 57.20209 + 2.144321*T$, $R^2 = 32.8012$ ---------------(1.3.1)

2. $Y = 1225.9790 + 53.63675*T$, $R^2 = 79.7038$ -------------(1.3.2)

3. $Y = 3084.9110 + 196.4274*T$, $R^2 = 88.8227$ -------------(1.3.3)

Where models (1.3.1), (1.3.2) and (1.3.3) represent the fishing industry, primary sector and the NSDP.The dependent variable Y stands for the income in rupees (crores) and T = Time variable (1980-81 = 1).

Model (1.3.1) has low $R^2$-Value, as it explains only 33 percent variability and hence not acceptable and also it is evident that the growth of income from fishing industry is not linear.

For models (1.3.2) and (1.3.3), the high values of $R^2$, (80 & 89 percent respectively) show that the data is well explained by these models. The standard errors are found to be well within reasonable limits (Table 1.5). This indicates a steady upward growth in respect of both primary sector and the NSDP.

**Regression output - PS and NSDP**

| | | Model 1.3.2 | Model 1.3.3 |
|---|---|---|---|
| Constant | : | 1225.9790 | 3084.9110 |
| S.E. of Y Est. | : | 125.6134 | 323.3814 |
| $R^2$ | : | 0.79704 | 0.88823 |
| No. of observations | : | 15 | 15 |
| DF | : | 13 | 13 |
| T Coefficient | : | 53.63675 | 196.4274 |
| S.E. of Coeft. | : | 7.50684 | 19.32574 |

As the fishing income over years was found to be non-linear, quadratic and cubic models were fitted and compared. The results are given below :

**Regression output - Fishing income**

| Models | $R^2$ | df | F | Sig | $b_0$ | $b_1$ | $b_2$ | $b_3$ |
|---|---|---|---|---|---|---|---|---|
| LIN | .328 | 13 | 6.35 | .026 | 5720.21 | 214.43 | | |
| QUA | .628 | 12 | 10.1 | .003 | 8141.18 | -640.03 | 53.40 | |
| CUB | .628 | 11 | 6.19 | .010 | 8060.04 | -587.46 | 45.45 | .3315 |

For fishing income, Quadratic and Cubic models give the same $R^2$-value (63 percent). The cubic model does not show any improvement over quadratic in $R^2$ value and also the coefficient $b_3$ is very low. Hence the quadratic model is more suitable, which is of the form

$Y = b_0 + b_1 T + b_2 T^2$

The model is $Y = 8141.18 - 640.03*T + 53.40*T^2$ ------------(1.3.4)

where Y is the fishing income in rupees lakhs.

The fact that the fishing income had a quadratic growth justifies our earlier observations that the fishing industry had a declining phase during 1985-90 and a recovery phase since 1990. Infact, this period (85-90) indicated about 21 percent decline over the previous 5 year period, resulting in lower contribution to the primary sector and lower per capita income of the fishermen. This aspect will be dealt with later in detail.

## 1.4 Model of fishing income on fish catch

Now we are interested how the fishing income is influenced by the fish catch. With this objective, a multiple regression model of fishing income on marine and inland catch was fitted.

$Y = b_0 + b_1 * X_1 + b_2 * X_2$, where Y is the FI and $X_1$ and $X_2$ are the marine and inland catches respectively.

**Table 1.4 : Fishing Income and Fish Landings -Kerala**

| Year | FI (Rs lakhs) | Inland 000 t | Marine 000 t | Total Landings 000 t |
|---|---|---|---|---|
| 1980-81 | 7743 | 25.53 | 26.81 | 52.34 |
| 1981-82 | 5797 | 26.06 | 30.53 | 56.59 |
| 1982-83 | 6958 | 26.39 | 34.79 | 61.18 |

| | | | | |
|---|---|---|---|---|
| 1983-84 | 7691 | 27.24 | 41.81 | 69.05 |
| 1984-85 | 6764 | 27.62 | 36.51 | 64.13 |
| 1985-86 | 7042 | 28.57 | 35.08 | 63.65 |
| 1986-87 | 5917 | 28.19 | 31.08 | 59.27 |
| 1987-88 | 4592 | 26.93 | 28.64 | 55.57 |
| 1988-89 | 6505 | 28.48 | 37.49 | 65.97 |
| 1989-90 | 5457 | 33.31 | 54.57 | 87.88 |
| 1990-91 | 9380 | 36.34 | 56.28 | 92.62 |
| 1991-92 | 8847 | 40.37 | 53.49 | 93.86 |
| 1992-93 | 9138 | 42.39 | 55.32 | 97.71 |
| 1993-94 | 9694 | 45.48 | 55.92 | 101.40 |
| 1994-95 | 10010 | 48.19 | 57.43 | 105.62 |

The results are furnished as below:

| | | |
|---|---|---|
| Multiple R | : | 0.79274 |
| $R^2$ | : | 0.62844 |
| Adjusted R square | : | 0.56652 |
| Standard Error | : | 1102.41705 |

Anova F = 10.14825 Signif F = 0.0026

**Regression : Dependent Variable FI variable in the equation**

| Variable | b | SE b | Beta | t | Sig t |
|---|---|---|---|---|---|
| Marine | 15.21325 | 55.56755 | 0.10551 | 0.274 | 0.7889 |
| Inland | 149.95146 | 82.86320 | 0.69741 | 1.810 | 0.0955 |
| (Constant) | 1882.58172 | 1272.47480 | | 1.479 | 0.1648 |

It is evident that though the $R^2$ value is reasonably high as 62.84 percent, the t values of the variables are not significant at acceptable levels (0.05) and as such the model is unacceptable.

Again linear models of FI on Inland, Marine and Total landings were tried separately. For Inland catch as independent variable, regression analysis shows,

| Variable | b | SE b | Beta | t | Sig t |
|---|---|---|---|---|---|
| Inland | 170.13491 | 36.46341 | 0.79128 | 4.666 | 0.0004 |
| (Constant) | 1865.56302 | 1224.90229 | | 1.523 | 0.1517 |

$R^2$ = .62612, Regression F= 21.77069     Sig F=.0004

Here $R^2$ value is 62.6 percent and beta =.79 but the constant in the model is significant only at 15 percent level. So this can not be taken as a good model.

For the marine catch as independent variable, R square value is only about 53 percent. Other results are :

Regression F= 14.48684     Signif F= 0.0022

**Variables in the equation**

| Variable | b | SE b | Beta | t | Sig t |
|---|---|---|---|---|---|
| Marine | 104.67620 | 27.50180 | 0.72598 | 3.806 | 0.0022 |
| (Constant) | 3006.11884 | 1203.99054 | | 2.497 | 0.0267 |

t values are significant at reasonable levels, but the model explains only about 53 percent of the variation.

Taking total catch as the independent variables,

| | | |
|---|---|---|
| Multiple R | : | 0.77296 |
| $R^2$ | : | 0.59747 |
| Adjusted R square | : | 0.56650 |
| Standard Error | : | 1102.43404 |

.Anova F = 19.29551 Signif F = .0007

| Variable | b | SE b | Beta | t | Sig t |
|---|---|---|---|---|---|
| Total catch | 68.55489 | 15.60667 | 0.77296 | 4.393 | 0.0007 |
| (Constant) | 2290.21062 | 1205.46344 | | 1.900 | 0.0799 |

The model explains about 60 percent of the variation though the t value for the constant term is significant at 8 percent level. Hence model can be accepted as a reasonably good one.

The model is Y= 2290.2106+68.5545*X ---------------------1.4.1)

where X = Total fish catch ('000 t), Y = Fishing income (Rs.crore)

Further modification of these models were probed by identifying and excluding one of the observations as outlier (1989-

90 entry) after plotting the data. Application of the Multiple regression model gives the results as follows:

| | | |
|---|---|---|
| Dependent variable | : | FI |
| Independent Variables | : | Marine, Inland catches |
| Multiple R | : | 0.89569 |
| $R^2$ | : | 0.80227 |
| Adjusted $R^2$ | : | 0.76632 |
| Standard Error | : | 793.82255 |

**Table 1.5 : Analysis of variance**

| | DF | Sum of squares | Mean Squares |
|---|---|---|---|
| Regression | 2 | 28124227.38106 | 14062113.69053 |
| Residual | 11 | 6931696.61894 | 630154.23809 |

F= 22.31535 Signif F = .0001

| Variable | b | SE b | Beta | t | Sig t |
|---|---|---|---|---|---|
| Marine | 106.49974 | 47.82531 | .75296 | 2.227 | .0478 |
| Inland | 31.14233 | 68.72152 | .15323 | 0.453 | .6592 |
| (Constant) | 2137.58213 | 919.19422 | | 2.325 | .0402 |

Model explains 80 percentage of the variability, but the S.E. b of Inland variable is high resulting in the non-significance of t and the beta (Inland) is very low. Hence the model cannot be regarded as an acceptable one.

Now, considering linear regression of FI over Inland catch, we have

| | | |
|---|---|---|
| Multiple R | : | 0.84447 |
| $R^2$ | : | 0.71313 |
| Adjusted R square | : | 0.68922 |
| Standard Error | : | 915.44802 |

**Regression analysis**

| Variable | b | SE b | Beta | t | Sig t |
|---|---|---|---|---|---|
| Inland | 171.63040 | 31.42413 | .84447 | 5.462 | .0001 |
| (Constant ) | 1964.93123 | 1056.2510 | | 1.860 | .0875 |

F=29.83060 Signif. F= .0001

High values of $R^2$ and Beta suggest the acceptability of a good model. SE of inland also is reasonable limits. But the constant term is significant only at 9 percent level.

The Regression model of fishing income (Y) over Marine catch,

| | | |
|---|---|---|
| Multiple R | : | 0.89363 |
| R square | : | 0.79858 |
| Adjusted R square · | : | 0.78179 |
| Standard Error | : | 767.08894 |

**Table 1.6 : Regression analysis**

Anova shows that F = 47.57581 Signif F = .0000

| Variable | B | SE B | Beta | t | Sig t |
|---|---|---|---|---|---|
| Marine | 126.39602 | 18.32484 | .89363 | 6.898 | 0.0000 |

| | | | | | |
|---|---|---|---|---|---|
| (Constant) | 2329.94008 | 787.8580 | | 2.975 | .0120 |

$R^2$ value is 80 percent, F is highly significant and SE's are well within reasonable limits and beta value is high (.8936).

The linear model of Y with the total catch (marine + inland) is also found to be equally good.

| | | |
|---|---|---|
| Multiple R | : | 0.8913 |
| $R^2$ | : | 0.79444 |
| Adjusted $R^2$ | : | 0.77731 |
| Standard Error | : | 774.9209 |

Anova gives F = 46.3776 (sig F = .0000)

| Variable | B | SE B | Beta | t | Sig t |
|---|---|---|---|---|---|
| Total catch | 75.87567 | 11.13868 | .89132 | 6.810 | .0000 |
| (Constant) | 1947.6423 | 852.1672 | | 2.286 | .0413 |

All the relevant values are well within resonable limits and model is well accepted. By excluding one outlier, the efficiency of model has been enhanced from 60 percent to 80 percent.

Thus we have four models using the modified data set.

$$Y = 2137.58213 + 106.49974X_1 + 31.14233X_2 \quad \text{------------(1.4.2)}$$

$$Y = 1964.93123 + 171.63040X_1 \quad \text{--------------------------------(1.4.3)}$$

$$Y = 2329.94008 + 126.39602X_1 \quad \text{--------------------------------(1.4.4)}$$

$$Y = 1947.64230 + 75.85567X_1 \quad \text{----------------------------------(1.4.5)}$$

where Y is the income from fishing industry(fishing income (in lakhs rupees)), X1, X2, are marine and inland catches respectively for the equation (1.4.2)('000 t).

X1 : Inland catch for equation ------------------------------(1.4.3)

X1 : Marine catch for equation -----------------------------(1.4.4)

and X1 : Total catch for equation -------------------------------(1.4.5)

Among these models, models (1.4.4) and (1.4.5) give $R^2$ value 0.80 and the coefficients are highly significant that they are best fits to the data and hence can be used for forecasting purposes.

**1.5 Forecasting**

Goodness of fit of the above models show that if the marine fish catch or the total catch is available, the income from fishing industry can be forecast by employing equation (1.4.4) and (1.4.5) as the case may be. The parabolic curvature of the fishing income may be attributed to the decline and rise in the marine and total catch during 1984-90 and 1990-95 respectively. Fishing income, PS and NSDP for 1995-96 can be computed by putting t value as t = 16 in the respective models.

**1.6 Inter-relations between sectors**

To find the inter-relations between fishing income ($X_1$), primary sector ($Y_1$) and NSDP ($Z_1$), linear models were fitted as follows:

$$Y_1 = 713.5533 + 12.6622 * X1, \; R^2 = 62.2677 \text{-----------} (1.6.1)$$

$$Z_1 = 1601.5130 + 41.0833 * X1, \; R^2 = 54.4678 \text{---------} (1.6.2)$$

$$Y1 = -947.5360 + 3.38587 * Z1, \; R^2 = 95.2591 \text{ ---------} (1.6.3)$$

where the coefficients in the equations (1.6.1) and (1.6.3) are highly significant. For (1.6.1), SE(a) = 171.27, SE(b) = 2.73 and for model (1.6.3), SE(a) = 210.60, and SE(b) = 0.21 ( a is the constant and b is the coefficient of the dependent variable).

Hence the model of Primary Sector on fishing income is satisfactory, where as the model of NSDP on Primary Sector proves to be of very good fit.

Further, a comparison of the Primary Sector's contribution to the NSDP appears to be worthwhile. Its share in 1960-61 was 55.98 % which gradually declined to 39.23 % in 1980-81 and further declined to 32.33 percent in 1994-95. It may well be interpreted that the thrust of Kerala's economy is slowly being shifted from the primary sector (fishing, Agriculture etc.) to the Secondary and tertiary sectors. This may be an indication of the growth and sustainability of the Kerala economy without much leaning on the traditional sector.

**1.7 Percapita income in relation to economic growth :**

A decreasing trend in the population growth rate has been observed for some time in the Kerala state. The average growth in population decreased to 6.51 percent in 1990-95 compared to 7.33 percent in 1985-90. Combined with this decreasing trend in population growth and the over all economic growth in the state, percapita income went up by 40 percent in the last 15 years. The period 1990-95 alone achieved an increase of 24 percent and this may be attributed to the substantial growth in NSDP during this period.

The state income in 1994-95 at constant prices is estimated at Rs.6461 crores as against Rs.6165 crores in 1993-94, registering a growth rate of 4.8 percent. At current prices the state income is estimated at Rs.21358 crores as compared to Rs.18837 crores in 1993-94. The percapita income in 1994-95 at constant prices is estimated at Rs.2113 as compared to Rs.2043 in 1993-94, registering a growth rate of 3.4%. Percapita income at current prices is estimated as rupees 6983 in 1994-95 against rupees 6242 in 1993-94, an increase of 11.9 %

Effort is made to study the relationship of the percapita income on the economic growth. Linear models were fitted to explain and measure the closeness of these relationships by taking percapita income in rupees as the dependent variable Y, and X1, X2 and X3 as explanatory variables for NSDP, PS and FI respectively. At present level of population growth, models are formulated as follows.

Models are $Y = 492.7525 + 0.002496*X1$, $R^2 = 98.6196$ ---(1.7.1)

$Y = 236.6655 + 0.008571*X2$, $R^2 = 96.5801$---(1.7.2)

$Y = 845.5518 + 0.108913*X3$, $R^2 = 60.5524$---(1.7.3)

S. Errors of Y Est. are 28.5740, 44.9751 and 152.7496 respectively. The SEs of X coeffts. are 0.000081, 0.000447 and 0.02438 respectively. Variability is explained as high as 98.62 percent in model (1.7.1) and 96.58 percent in model (1.7.2). With these well defined models, percapita income can be predicted.

The model means , an increase of 1000 lakh rupees in the variable NSDP would enhance the percapita income by 2.5 rupees, and the same increase in PS would effect an increase of 8.6 rupees in the per capita income.

Also, since the assumptions of exact relations may not be appropriate in econometric models, the linear relations are only approximation of the real situation. This necessities the inclusion of a stochastic or disturbance term $\varepsilon$ in each relation.

## 1.8 Contribution of fishing industry

The contribution of Fishing industry to PS and NSDP for different periods are given in Table 1.7. Accordingly about 5 percent is the contribution to the Primary Sector (constant prices) and 9 percent at current prices during 1990-95.

**Table 1.7 : Contribution of Fishing Industry**
(Figs. in percentages) Base year 1980-81

| | At Constant Prices | | At current prices | |
|---|---|---|---|---|
| Year | Primary sector | Net State Domestic Product | Primary sector | Net State Domestic Product |
| 1980-85 | 4.90 | 1.83 | 4.38 | 1.67 |
| 1985-90 | 3.85 | 1.37 | 5.46 | 1.85 |
| 1990-95 | 4.72 | 1.63 | 8.84 | 3.08 |

## 1.8 Growth of infrastructure

The infrastructure facilities in the fisheries sector have considerably improved over years. It has contributed to enhancement of fishing activities and the resultant catch. The mechanised and motorised fishing have come to completely dominate the non-mechanised traditional fishing. The following table furnishes the statistics of the fishing vessels in Kerala during 1990-95.

**Table 1.8 : Growth of Fishing Crafts ***

| YEAR | Mechanised crafts | Motorised country crafts | Non-motorised country crafts |
|---|---|---|---|
| 1990 | 3742 | 11374 | 26137 |
| 1991 | 3737 | 9914 | 20545 |
| 1992 | 3765 | 12913 | 26669 |
| 1993 | 3773 | 15336 | 27873 |

| | | | |
|---|---|---|---|
| 1994 | 3790 | 17102 | 27899 |
| 1995 | 4206 | 17362 | 28456 |

* Source : Marine Fisheries of Kerala at a glance, 1996. Directorate of Fisheries , Govt. of Kerala.

The mechanised crafts increased by 12.4 percent, motorised crafts by 52.6 and the non-mechanised country crafts by 8.8 percent during 1990-95. The catch composition of these different types of crafts show that 45.5 percent of total catch is landed by mechanised vessels, 50.7 by motorised crafts and 3.8 percent by non-mechanised traditional crafts as per the estimate of 1996. The mechanised crafts increased its share of 38.2 % in 1991 to 45.5 % in 1996 as estimated by Central Marine Fisheries Research Institute. On the other hand, the motorised crafts and non-mechanised crafts showed a decrease from 54.8 to 50.7 percent and from 7.0 to 3.8 percent respectively during the last five years ending 1995. Consequently, the catch per mechanised boat increased from 57.5 to 61.9 tonnes while the catch per boat decreased from 31.2 to 16.7 and from 1.91 to 0.76 tonnes for motorised and non-motorised vessels respectively during the same period.

**Gears**

Of the total number of 71,811 gears used both for marine and inland fishing, there were 5806 trawl nets, 23581 gillnets, 1224 ring seines, 1056 boat seines, 5037 encircling nets, 1507 shore seines, 1591 drift nets, 9290 cast nets, 14524 hook & lines, 40 purse seines and 8155 other types of nets (Anon, 1993)

**Fish Processing**

The number of freezing plants in Kerala coast is 121 with an installed capacity of 1581 tonnes per day during 1995. This is about 22 % of the installed capacity at the all India level. Also, compared with the all India figures, this state enjoys 31 % of the freezing plants, 35 % of the ice making plants and 36 % of the cold storages. Number of exporters increased from 134 in 1990 to 290 in 1996 (Anon, 1997).

**Inland Sector**

Kerala has rich water resources with an estimated area of 360,535 hectares which produced 49, 586 tonnes of fish in 1995-96 (Anon, 1996a).

## 1.9 Per capita out put of fishermen in mechanised sector

There has been a spectacular growth in the mechanised sector during the last two decades in Kerala both in the number of crafts and in the total fish landings. This can be attributed to the fast technological developments in fishing techniques, design of gears and crafts. The highly receptive fishermen in this state also helped the transfer of technology to the primary producers at a reasonable pace.

The percapita output by fishermen in the mechanised sector is the ratio of the quantity of fish landed to the number of fishermen in this sector. The number of fishermen engaged in mechanised fishing increased from 16,600 in 1976 to 29,800 in 1995. The year-wise fish catch, number of fishermen and the per capita output are furnished in the following table. (Table 1.9).

Table 1.9 : Percapita Production of Fish per fisherman in the Mechanised sector - Kerala

| Year | Catch (Tonnes) | Number of fishermen | Percapita out put (Tonnes) |
|---|---|---|---|
| 1976 | 58185 | 16652 | 3.49 |
| 1977 | 106073 | 17151 | 6.18 |
| 1978 | 117572 | 17665 | 6.66 |
| 1979 | 94779 | 18194 | 5.21 |
| 1980 | 135305 | 18740 | 7.22 |
| 1981 | 96321 | 19302 | 4.99 |
| 1982 | 148668 | 19881 | 7.48 |
| 1983 | 197689 | 20477 | 9.65 |
| 1984 | 263532 | 21091 | 12.49 |
| 1985 | 248411 | 22181 | 11.20 |
| 1986 | 316067 | 22846 | 13.83 |
| 1987 | 263362 | 23531 | 11.19 |
| 1988 | 436316 | 24237 | 18.00 |
| 1989 | 613960 | 24965 | 24.59 |
| 1990 | 620196 | 25714 | 24.12 |
| 1991 | 524877 | 26485 | 19.82 |
| 1992 | 530643 | 27280 | 19.45 |
| 1993 | 539540 | 28098 | 19.20 |
| 1994 | 547648 | 28941 | 18.92 |
| 1995 | 512272 | 29809 | 17.19 |

Source :i) CMFRI special publication No. 35 and various numbers of MFIS
:ii) Kerala fisheries an over view -different issues.

A suitable model for predicting the percapita quantity output was tried using the quantity of fish landed and time as explanatory variables. Time variable has another significance that it indirectly represents the number of fishermen since their number is observed to increase steadily over time. The analysis covers a duration of 20 years from 1976 to 1995. The time factor is represented by 1 for 1976 and the same is continued till 1995 when time is taken to be 20.

A regression model using percapita out put as the dependent variable and the fish catch and time as independent variables was fitted, the results of which are furnished below.

| | | |
|---|---|---|
| Multiple R | : | 0.9937 |
| R Square | : | 0.9854 |
| Adjusted $R^2$ | : | 0.9837 |
| Standard error | : | 0.8525 |

**Table 1.10 : Analysis of Variance**

| | DF | Sum of squares | Mean square |
|---|---|---|---|
| Regression | 2 | 834.3048 | 417.1524 |
| Residual | 17 | 12.3551 | 0.7268 |

F=573.9830 Signif F= .0000

| Variable | b | SE b | Beta | t | Sig t |
|---|---|---|---|---|---|
| X | 4.07502E-05 | 2.60273E-06 | 1.2204 | 15.657 | .0000 |
| T | -.28273 | .08795 | -.2506 | -3.215 | .0051 |
| (Const.) | 3.03084 | .39691 | | 7.636 | .0000 |

The results indicate the $R^2$ value as high as 98.5 percent and the F-value of the Anova is highly significant. The b values of both variables X and T (representing the catch and time respectively) and the constant term are also highly significant. Thus it is observed that the model is very well fitted to the data and hence this can be used for prediction.

An increase in the fish landing will enhance the percapita output where as the -ve sign of the coefficient of T indicates that an increase in time, and the consequent increase in the number of fishermen adversely affect the per capita.

## 1.10 Gross Revenue at beach price and current fishing income

Table 1.11 furnishes the gross revenue at beach prices (Rs. lakhs) of all landed fish varieties at the beach and the current fishing income (Rs. lakhs). The gross revenue at beach price is arrived at by multiplying a matrix (Q) of quantity of fish landed with another matrix (P) of price per kilogram of fish such that

$V = (V1, V2, \ldots\ldots.Vn)$ where $Vi = \Sigma$ Pij qij

$$P = \begin{vmatrix} p11 & p12 & \ldots\ldots & p1n \\ p21 & p22 & \ldots\ldots & p2n \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ pm1 & pm2 & \ldots\ldots & pmn \end{vmatrix}$$

and

$$Q = \begin{vmatrix} q21 & q22 & \dots & q2n \\ . & & & \\ . & & & \\ . & & & \\ . & & & \\ qm1 & qm2 & \dots & qmn \end{vmatrix}$$

$q_{ij}$ is the quantity (in kgs) of ith variety at $j^{th}$ year and pij is the average beach price (in Rupees) per kilogram of the ith variety of fish in the $j^{th}$ year.

Average beach price for 14 major varieties of fish and `miscellaneous' variety (which includes all of the rest of the 14 varieties) are regularly estimated along with species-wise catch by the Kerala State department of fisheries (Source: Marine Fisheries of Kerala at a Glance (1991to1995). The total out-put (value) based on the average beach prices and the fishing income (at current prices) for the period 1980-95 are furnished in the table 1.11.

**Table 1.11 : Total Beach Prices Vs Fishing Income**

| Year | Total beach price Rs. lakhs | *Fishing Income (Rs. lakhs-current prices) |
|---|---|---|
| 1980-81 | 8222 | 7743 |
| 1981-82 | 6243 | 6292 |
| 1982-83 | 8358 | 7923 |

| | | |
|---|---|---|
| 1983-84 | 9532 | 8938 |
| 1984-85 | 9439 | 8942 |
| 1985-86 | 12760 | 11777 |
| 1986-87 | 13551 | 12104 |
| 1987-88 | 13413 | 10661 |
| 1988-89 | 20960 | 16845 |
| 1989-90 | 34661 | 28370 |
| 1990-91 | 46471 | 37193 |
| 1991-92 | 62998 | 50685 |
| 1992-93 | 66496 | 56049 |
| 1993-94 | 87729 | 56789 |
| 1994-95 | 96624 | 58067 |

*Ref:i)Kerala Fisheries Facts and Figures 1990. ii) Marine Fisheries of Kerala at a Glance, 1991 to 1996 (Directorate of Fisheries)

Considering the fishing income (Rs. lakhs) as dependent variable Y and the gross revenue based on beach price (Rs. lakhs) as independent variable X, regression model was fitted which gives $R^2$ = .96099 and adjusted $R^2$ = .95799.

ANOVA gives

F = 320.26730, Sig at .0000 and the model is

$$Y = 3718.72534 + 0.64850X$$

and the constant and regression coefficient were found to be highly significant at 0.0000 and 0.0393 respectively. Thus the model is a very good fit.

| Variable | B | SE B | Beta | T | Sig T |
|---|---|---|---|---|---|
| X | .648501 | .036237 | .980302 | 17.869 | .0000 |
| (Constant) | 3718.72533 | 1623.43623 | | 2.291 | .0393 |

The results shows that the model is a good fit.

## 1.11 Principal Component Analysis on fish catch

To understand the pattern of variance in catch arising out of the fifteen selected groups of fishes over the fifteen year period of study, Principal Component Analysis (PCA) was carried out. Incorporating the fifteen years, fifteen Principal Components (PC's) were worked out. Table 1.12 gives the eigen values (PC-wise variance) together with the percentage accounted by each PC and the cumulative percentage. Table 1.13 gives the eigen vectors (PC Coefficients) generated for each PC in the process. Table 1.14 gives the PC score for each PC for each of the groups of fish and Table 1.15 the percentage variance accounted by each group of fish.

Table 1.12 shows that the fish PC has accounted for 48% (i.e.) nearly half of the total variance, while the first five have accounted for nearly 90%. The first ten PC's have accounted for practically the complete total variance, with the remaining five PC's contributing very little. Because of the inherent variability in fish catch, the number of PC's required for accounting for the full variance is some what high as compared to in other areas where the number of PC's required for the same percentage is normally very less. The relative importance of the contribution from the different years can be gauged from the eigen vectors. The first year's contribution was more or less uniform over all the PC's, while in the case of others it was different, with each year's contribution varying with each PC.

**Table 1.12 : Eigen Values (PC Variance)**

| PC number | Variance | Percentage of the total variance | cumulative percentage |
|---|---|---|---|
| 1. | 7.23 | 48.2 | 48.2 |
| 2. | 1.90 | 12.6 | 60.8 |
| 3. | 1.78 | 11.9 | 72.7 |
| 4. | 1.57 | 10.5 | 83.2 |
| 5. | 0.86 | 5.7 | 88.9 |
| 6. | 0.53 | 3.5 | 92.4 |
| 7. | 0.40 | 2.7 | 95.1 |
| 8. | 0.30 | 2.0 | 97.1 |
| 9. | 0.18 | 1.2 | 98.3 |
| 10. | 0.16 | 1.1 | 99.4 |
| 11. | 0.07 | 0.5 | 99.9 |
| 12. | 0.02 | 0.1 | 100.0 |
| 13. | 0 | 0 | 100.0 |
| 14. | 0 | 0 | 100.0 |
| 15. | 0 | 0 | 100.0 |
| Total | 15.0 | 100.0 | |

Table 1.14 shows that the maximum PC score has come for PC1 from Prawns, other crustaceans and miscellaneous group of fishes. Next come sardine and corant for PC1. Elasmobranches for PC2, seerfish for PC3, saurida sourus for PC4 have contributed high PC scores. For the rest of the PC's no particular group of fishes has contributed in any significant manner. Table 1.15 giving the percentage variance for each group of fishes for the whole period is more or less in conformity with the above. The maximum contribution of 20% of the variance has come from other crustaceans followed by miscellaneous group of fishes with nearly 14% of the total variance. Prawns, sardine and sourus and elasmobranches are the groups which have contributed to the total variance in a substantial way.

## Table 1.13 : Eigen Vectors

### PC number

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Elasmobranches | 0.80 | -2.91 | -0.86 | -2.11 | 0.29 | -0.07 | -0.40 | 0.22 | 0.82 | 0.28 | -0.02 | -0.03 | 0 | 0 | 0 |
| 2. | Cat fish | 1.00 | -0.20 | -1.58 | -1.75 | -1.46 | 0.95 | 0.58 | 0.48 | -0.76 | -0.02 | -0.18 | 0.02 | 0 | 0 | 0 |
| 3. | Sardine | 2.48 | 0.14 | -0.50 | -0.28 | 0.63 | -1.01 | -0.44 | -0.53 | -0.32 | -0.58 | -0.17 | 0.14 | -0.02 | 0 | 0 |
| 4. | Anchoviella | 1.70 | -0.42 | -0.97 | -0.17 | 0.16 | -0.77 | -0.30 | -0.25 | -0.32 | 0.13 | 0.56 | 0.10 | 0 | 0 | 0 |
| 5. | Saurida & Sauris | 0.73 | -1.92 | 0.47 | 2.68 | -1.82 | 0.23 | -0.23 | -0.68 | 0.05 | 0.27 | -0.08 | 0 | 0 | 0 | 0 |
| 6. | Perches | 1.64 | 1.37 | -0.78 | 1.64 | -0.04 | 0.13 | -1.04 | 1.35 | 0.06 | 0.05 | 0.12 | -0.03 | 0 | 0 | 0 |
| 7. | Scianids | 1.74 | 1.59 | 0.38 | 0.14 | 0.72 | 0.28 | 0.88 | -0.16 | 0.16 | 0.86 | 0 | 0.23 | 0 | 0 | 0 |
| 8. | Ribbon fish | 2.20 | 0.98 | -0.37 | 0.27 | 0.64 | 0.25 | 0.58 | -0.32 | 0.26 | 0.09 | 0.10 | -0.33 | -0.02 | 0 | 0 |
| 9. | Carand | 2.36 | 0.70 | -0.54 | 0.18 | 0.51 | -0.13 | -0.16 | -0.43 | -0.07 | -0.14 | -0.48 | -0.12 | 0.04 | 0 | 0 |
| 10. | Mackerel | 1.69 | 0 | 1.54 | 0.04 | -0.08 | 1.10 | 0.50 | 0.04 | 0.47 | -0.92 | 0.26 | 0.10 | 0 | 0 | 0 |
| 11. | Seer fish | -0.67 | -0.54 | 2.96 | -0.20 | 0.40 | -0.40 | -0.13 | 0.68 | -0.06 | 0.10 | -0.36 | 0.05 | -0.02 | 0 | 0 |
| 12. | Tunnies | -1.61 | -0.79 | 2.12 | -0.53 | 0.21 | -0.40 | 0.22 | 0.02 | -0.71 | 0.12 | 0.29 | -0.17 | 0.02 | 0 | 0 |
| 13. | Prawns | -3.58 | 2.01 | -0.15 | -0.72 | -1.74 | -1.31 | 0.37 | 0.02 | 0.54 | -0.12 | 0 | -0.01 | 0 | 0 | 0 |
| 14. | Other Crustaceans | -5.59 | -1.30 | -1.86 | 1.67 | 1.24 | -0.04 | 0.80 | 0.27 | -0.06 | -0.23 | -0.07 | 0.04 | 0 | 0 | 0 |
| 15. | Others | -4.88 | 1.28 | 0.13 | -0.87 | 0.34 | 1.20 | -1.23 | -0.69 | -0.04 | 0.11 | 0.02 | 0.02 | 0 | 0 | 0 |
| 16. | Variance | 7.23 | 1.90 | 1.78 | 1.57 | 0.86 | 0.53 | 0.40 | 0.30 | 0.18 | 0.16 | 0.07 | 0.02 | 0 | 0 | 0 |

## Table : 1.14 PC Scores

### PC number

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 1979-80 | 0.27 | 0.25 | 0.26 | 0.28 | 0.27 | 0.27 | 0.28 | 0.28 | 0.27 | 0.28 | 0.28 | 0.28 | 0.24 | 0.14 | 0.17 |
| 2. | 1980-81 | 0.15 | 0.12 | 0.25 | 0.13 | 0.098 | -0.13 | -0.0045 | 0.015 | 0.17 | 0.067 | 0.077 | 0.022 | -0.28 | -0.62 | -0.59 |
| 3. | 1981-82 | -0.094 | -0.63 | 0.023 | 0.094 | 0.25 | 0.34 | 0.11 | 0.14 | 0.050 | 0.037 | 0.022 | -0.037 | -0.41 | 0.33 | -0.29 |
| 4. | 1982-83 | -0.15 | -0.59 | 0.088 | -0.086 | 0.14 | -0.026 | -0.071 | -0.16 | 0.021 | 0.026 | 0.30 | 0.15 | 0.50 | -0.42 | 0.14 |
| 5. | 1983-84 | -0.41 | 0.34 | -0.22 | -0.083 | 0.56 | 0.40 | 0.016 | -0.13 | -0.091 | -0.059 | -0.097 | -0.20 | 0.23 | -0.10 | -0.20 |
| 6. | 1984-85 | 0.43 | -0.16 | 0.15 | 0.31 | 0.31 | -0.12 | -0.34 | 0.046 | -0.0055 | -0.16 | -0.49 | -0.25 | 0.31 | 0.08 | -0.036 |
| 7. | 1985-86 | -0.028 | 0.072 | 0.12 | -0.031 | 0.43 | -0.094 | -0.40 | -0.30 | 0.11 | 0.15 | 0.079 | 0.076 | -0.49 | -0.048 | 0.49 |
| 8. | 1986-87 | -0.66 | 0.0058 | 0.28 | 0.12 | 0.022 | -0.40 | -0.026 | 0.37 | 0.23 | 0.18 | -0.28 | 0.033 | 0.066 | 0.083 | 0.013 |
| 9. | 1987-88 | 0.014 | 0.084 | 0.025 | -0.081 | 0.27 | -0.47 | -0.053 | -0.25 | -0.11 | -0.18 | 0.32 | 0.33 | 0.13 | 0.46 | -0.39 |
| 10. | 1988-89 | -0.13 | 0.022 | 0.15 | 0.24 | 0.022 | 0.028 | 0.28 | -0.079 | 0.24 | -0.83 | 0.020 | 0.065 | -0.11 | -0.081 | 0.20 |
| 11. | 1989-90 | 0.12 | 0.025 | 0.40 | -0.56 | 0.21 | -0.086 | 0.096 | 0.45 | -0.31 | -0.19 | 0.16 | -0.30 | -0.053 | -0.029 | 0.10 |
| 12. | 1990-91 | -0.19 | 0.10 | 0.56 | 0.20 | -0.32 | 0.29 | -0.33 | -0.26 | -0.11 | -0.00017 | 0.28 | -0.30 | 0.088 | 0.18 | -0.11 |
| 13. | 1991-92 | -0.037 | -0.046 | 0.029 | 0.42 | 0.13 | -0.29 | 0.52 | -0.23 | -0.47 | 0.21 | 0.062 | -0.32 | -0.072 | -0.057 | 0.14 |
| 14. | 1992-93 | -0.036 | 0.025 | -0.45 | 0.31 | 0.027 | -0.16 | -0.30 | 0.40 | 0.094 | -0.11 | 0.53 | -0.34 | -0.021 | -0.020 | 0.028 |
| 15. | 1993-94 | 0.10 | -0.037 | -0.014 | -0.28 | 0.0071 | -0.16 | 0.25 | -0.30 | 0.64 | 0.12 | 0.063 | -0.52 | 0.084 | 0.14 | -0.030 |

Table 1.15 : Fish - group wise contribution to variance : percentage

| No. | Fish - group | Percentage variance |
|---|---|---|
| 1. | Elasmobranches | 7.4 |
| 2. | Catfish | 5.2 |
| 3. | Sardine | 4.3 |
| 4. | Anchoviella | 2.5 |
| 5. | Saurida & Saurus | 7.6 |
| 6. | Perches | 5.2 |
| 7. | Sciainids | 3.8 |
| 8. | Ribbon fish | 3.4 |
| 9. | Carana | 3.5 |
| 10. | Mackerel | 3.8 |
| 11. | Seer fish | 5.1 |
| 12. | Tunnies | 4.3 |
| 13. | Prawns | 10.0 |
| 14. | Other crustaceans | 20.1 |
| 15. | Others | 13.8 |
| Total | | 100.0 |

## Reference

Anon (1961). *Economic Review 1960*, Govt. of Kerala.

Anon (1981). *Facts and Figures : 1980*. Department of Fisheries, Govt. of Kerala.

Anon (1991). *Facts and Figures : 1990*. Department of Fisheries, Govt. of Kerala.

Anon (1992, 1993). *Marine Fisheries of Kerala at a Glance, 1991 & 1992*, Directorate of Fisheries, Govt. of Kerala.

Anon (1993). *Kerala Fisheries – An Overview-1992*. Dept. of Fisheries, Govt. of Kerala

Anon (1994, 1995). *Marine Fisheries of Kerala at a Glance, 1993 & 1994*, Directorate of Fisheries, Govt. of Kerala.

Anon (1995, 1996). *Economic Review-1994 & 1995*, Govt. of Kerala.

Anon (1995). *List of Fish Processing Units in Kerala 1995*. Marine Products Export Development Authority, Cochin.

Anon (1996, 1997). *Marine Fisheries of Kerala at a Glance, 1995 & 1996*, Directorate of Fisheries, Govt. of Kerala.

Anon (1997). *Handbook of Fishery Statistics 1996*, Ministry of Agriculture, Govt. of India.

Anon (1997a). *Inland Fisheries of Kerala at a Glance, 1996*. Dept. of Fisheries, Govt. of Kerala.

Chatfield, C and Collins, A.J. (1980). *Introduction to Multivariate Analysis*. Chahpman and Hall, New York.

Draper, N.R. and Smith, H (1981). *Applied Regression Analysis*, 2nd Edn., John Wiley and Sons, New York.

# APPLICATION OF NONLINEAR MODELS IN FISHERIES

G. Rajagopalan Unnithan "Stochastic models in fishery economics with special reference to Kerala " Thesis. Department of Statistics , University of Calicut, 1999

# CHAPTER 2

CHAPTER 2

# APPLICATION OF NONLINEAR MODELS IN FISHERIES

## 2.0 Introduction

Trend analysis of the time series data on marine fish landings is of much importance in interpreting the developments taking place in fisheries and for planning and policy making for the future. Both fishery dependent and independent factors reflect in the fish landings over time and the fisheries potential is estimated on the relative rate of growth in landings. Identification of appropriate models to describe the growth pattern in the marine fish catch forms the basis for fishery forecasting.

Nonlinear growth models describe growth behaviour over time in many fields. In the field of agriculture or biology, the growth occurs in plants or in animals and in economics, growth of production and supply of food material (Draper and Smith, 1966). The type of model needed in a specific situation depends on the type of growth that occurs. In general, growth models are mechanistic in nature, rather than empirical in the sense that they usually arise as a result of making assumptions about the type of growth, writing down differential or difference equations that represent these assumptions and then solving them to obtain a growth model. The utility of such models is that they help us to gain an insight into the underlying mechanism of the system and at the same time, they are of immense help in efficient management. In this chapter an attempt is made to study the growth behaviour of marine fish catch in Kerala through the application of nonlinear models.

## 2.1 Nonlinear Models

Method of least squares is widely used to fit models which are linear in parameters and they are of the type

$$Y = a_0 + a_1X_1 + a_2X_2 + \dots\dots\dots\dots + a_pX_p + \varepsilon \text{ ---------------(2.1.1)}$$

where Y is the dependent variable, $X_i$ are independent variables, $\varepsilon$ is the error term and $a_i$ are parameters to be estimated. However, in reality the relationship between variables is seldom linear.

A nonlinear statistical model is one in which atleast one of the parameters appears nonlinearly. Examples of such models are

$$Y(t) = \exp\ (at + bt^2 + \varepsilon) \text{ ---------------------------------------------(2.1.2)}$$

$$Y(t) = at + \exp\ (-bt) + \varepsilon \text{ ----------------------------------------------(2.1.3)}$$

where a, b are the parameters to be estimated, t is the predictor variable and $\varepsilon$ is the random error term with $E(\varepsilon) = 0$, $V(\varepsilon) = \sigma^2$.

The model (2.1.2) can be transformed into a linear form by means of transformation by taking logarithms to the base e.

$$\text{Thus } \operatorname{Ln} Y = at + bt^2 + \varepsilon \text{ -------------------------------------(2.1.4)}$$

This is of the form of equation (2.1.1) and is linear in parameters. Since it can be transformed into a linear form, the model given in equation (2.1.2) is said to be intrinsically linear. A model which cannot be converted into a form linear in parameters is said to be intrinsically nonlinear.

## 2.2 Review

Von Bertalanffy (1938) proposed a simple non-linear growth model of body length of fish as a function of age which has become one of the corner stones of fishery biology. A number of models with nonlinear approach followed this mainly in the field of fish population dynamics. Ricker (1946) investigated the production and utilisation of fish population and Beverton and Holt (1957) studied the dynamics of exploited fish population. Bartlett (1960) formulated stochastic population models in Ecology. Surplus-yield model for optimising exploited fish populations was brought out by Fox (1970). Clark (1976) studied the dynamic pool models. Apart from many other similar studies, Box (1971) presented the bias in nonlinear estimation and Bates and Watts (1980) investigated the relative curvature measures of nonlinearity. A statistical study of a seasonal growth model for fishes was conducted by Hoenig and Hanumara (1982). Hanumara and Hoenig (1987) made empirical comparison of a fit of linear and nonlinear models for seasonal growth in fish. Another similar study was carried out by Pawlak and Hanumara (1991) in which they compared the nonlinear growth models for fisheries. Schnute (1981) presented a new comprehensive growth model which relates to growth acceleration in fish. The growth models in fisheries, as indicated by these references, have been applied mainly in respect of biological growth of fish population. In the fishery economic analysis, nonlinear statistical models were fitted to catch data of Bombay duck off Maharashtra coast (Kurian, 1989). Exponential hyperbolic and power models were fitted to catch - effort data for a period of ten years ending 1984. Methodologies for fitting nonlinear models are detailed by Draper and Smith (1981), Bates and Watts (1988), Gallant (1987) and Ross (1990).

## 2.3 Growth models and assumptions

Growth models have been used for long, usually to provide a mathematical summary of size Vs time on the growth of organisms. An account of some of the known growth models is given below.

***Malthus Model***

Consider a growth pattern in which the rate of growth of population size at a particular time t is directly proportional to the number at the instant. Malthusian law states that if N(t) denotes the population size at time t and r is the intrinsic growth rate, then the rate of growth of population size is

$$dN/dt = rN \qquad \text{(2.2.1)}$$

This means that the rate of increase at any instant is proportional to the number at that instant.

Integrating, $N(t) = N_0\exp(rt)$ ------------------------------------------(2.2.2)

where $N_0$ denotes the population size at $t=0$. This represents the well known exponential growth for $r>0$ and $N(t) \to \infty$ as $t\to \infty$. It gives an exponential decrease when $r<0$ and $N(t) \to 0$ as $t\to\infty$.

***Monomolecular model***

In an environment, consider another growth situation in which the rate of growth is directly proportional to the amount of growth yet to be achieved. If we denote the limiting size or carrying capacity of the system by K,

$$dN/dt = r(K-N) \text{ ------------------------------------------(2.2.3)}$$

Integrating equation (2.2.3) we get

$\ln[(K-N_0)/(K-N)] = rt$

or $N(t) = K-(K-N_0)\exp(-rt)$ --------------------------------------------(2.2.4)

Equivalently, $N(t) = K[1-\beta\exp(rt)]$ ----------------------------------(2.2.5)

where $\beta = (K-N_0)/K$. The curves for different values of $\beta$ are described by Draper and Smith (1981).

***Logistic model***

Verhulst proposed a modification to the Malthusian law in 1838. Eighty years later R. Pearl and L.J. Reed independently gave the logistic growth model based on the concept of two opposing forces, biotic potential and environmental resistance, where the former is the inherent ability of a species to survive and reproduce at a rate `r' the intrinsic rate of natural increase and the latter is the sum total of all the forces in the environment which increase mortality.

This model is represented by the differential equation

$$dN/dt = rN(K-N)/K$$

$$\text{or } dN/dt = rN(1-N/K), \text{ for } r>0 \text{ ---------------------(2.2.6)}$$

In the multiplying factor (1-N/K), the term N/K measures the retarding force due to environmental resistance. The value of the force (N/K) is negligible when N is small, but approaches Unity as $N \to K$.

The equation (2.2.6) is the famous logistic growth curve given by Verhulst in 1838. Comparing with equation (2.2.4), this relationship gives the growth rate relative to present size, (dN/dt)/N that declines linearly with increasing N. Integrating the equation (2.2.6) and substituting for c, the constant of integration, we get

$$N(t) = K/[1+(K/N_o-1)\exp(-rt)]$$

$$\text{or } N(t) = K/[1+\beta\exp(-rt)], \text{ where } \beta = (K-N_o)/N_o \text{ \_\_\_\_\_\_(2.2.7)}$$

which is the fundamental equation of the logistic growth model. This equation has been extensively used in population dynamics to model growth of population. This curve has an S-shape and at $t=0$, N(t) is the starting growth value $N_0$ and at $t = \infty$, $N(t) = K$ which is the limiting growth value. $K>0$, the slope of the curve is always positive and the curve shape is symmetric about its point of inflection.

***Gompertz model***

Another model which is of much use in biological studies is the Gompertz model having a sigmoid type of behaviour and is not symmetric about its point of inflexion.

The differential equation for this model is

$dN/dt = rN \log_e (K/N)$ ------------------------------------------------(2.2.8)

On integration, this gives the form

$N(t) = K\exp[(\log N_0/K) \exp(-rt)]$ ------------------------------------(2.2.9)

***Richard's model***

If N(t) denotes the population size at time t, $r>0$ denotes the intrinsic growth rate, and K is the carrying capacity, then the relevant differential equation is of the form,

$dN/dt = r.N(K^m-N^m)/(mK^m)$ ---------------------------------(2.2.10)

where r, m and K are constants, $r>0$, $K>0$, $-1\leq m <\infty$, $m \neq 0$ (Richard's 1959)

Integrating the relation (2.2.10),

$N(t) = KxN_0/ [N_0+(K^m-N_0^m)\exp(-rt)$ ------------------------------(2.2.11)

which is a four parameter model.

For values m=-1, 1 and 0, in the relation (2.2.11), we get the differential forms of monomolecular, logistic and Gompertz models respectively.

***Von Bertalanffy model***

The growth model presented was of the form

$N(t) = \{K^{1-m} - \theta e^{-rt}\}^{1/(1-m)}$ --------------------------------------------(2.2.12)

where the parameters K, θ, r and m are to be estimated. Bertalanffy (1941; 1957) imposed limits on m, but subsequently Richards (1959) used its value over other ranges of m. For values of $m=0$, and 2, the function becomes monomolecular and logistic respectively. When $m \to 0$, the curve takes the Gompertz form. Also, when $m>1$, θ is negative and positive when $m<1$.

***Bass model***

On the lines of logistic model, Bass, in his adoption of technology studies, introduced in addition to density dependent growth, a growth which is simply a fraction of the potential adopters (constant * Potential adopters), expressed by a differential equation

$\frac{dN}{dt} = [p + (q/M)N](M-N)$ --------------------------------------------(2.2.13)

where M is the upper limit of potential adopters and N, the number of adopters at a given time and $N/M \to 1$ as $N \to M$, and p, q represent the external influence and internal influence respectively.

The equation (2.2.13) has a solution

$N(t) = M\{[1 - e^{-(p+q)t}] / [1 + (q/p)e^{-(p+q)t}\}$ ----------------------------(2.2.14)

where $N(t) = 0$.

This model will be dealt with more details in the next section on model applications.

## 2.4 Estimation of parameters for nonlinear models

The nonlinear statistical models obtained by adding an error term to the deterministic models mentioned above are to be solved for parameter estimates. The parameter estimates can be obtained by employing iterative procedures. Three of these methods are (i)linearisation, (ii) steepest descent and (iii) Levenberg - Marquardt's compromise. Draper and Smith (1981) have described these methods in detail.

The linearisation (or Taylor series) method uses the results of linear least square theory in a succession of stages. This method will converge rapidly provided the vicinity of the true parameter value has been attained, otherwise it may not converge at all. In the steepest descent method, even though the initial trial values which may be intelligent guesses or based on any available information, are far from true parameter values, it may converge. But the convergence will be very slow at the later stages of interative process. Thus neither of these methods appear to be ideal. Hence, the most commonly used method is the Marquardt's method which is a compromise between the other two methods, as this one converges and does not slow down at the later stages of the iterative process. Standard computer packages are available now to fit the nonlinear models. In this chapter, the parameter estimation is done based on Levenberg - Marquardt algorithm using the SPSS/PC+software package (1990)

## 2.5 Initial parameter estimates

Initial estimates are required for nonlinear estimation procedures and choice of good initial values is very crucial. Good initial values help the convergence very fast, poor values may even lead to wrong final values. The initial values may be only intelligent guesses or preliminary estimates based on available information. Known values for similar systems or values computed from theoretical considerations also can be made use of for the purpose. All such values may be considered as meaningful guesses.

At present there is no general method available for making initial estimates. We can make use of some of the known methods such as,

(i) Substitute for p sets of observations into the model if there are p parameters, ignoring the error terms and solve the resulting p equations.

(ii) Linear regression can be used for obtaining initial values, if the model could be transformed into a linear form by means of some transformation.

(iii) Consider the behaviour of the response function as the Xi go to zero or infinity and substitute in for observations that most nearly represent those conditions and solve the resulting equations.

(iv) If all the above methods fail, graphical method may be used for plotting the data and thereby obtain a visual estimate of the values.

## 2.6 Application of growth models in marine fish landings

***Malthus model for the all india landings***

Marine fish landings of India (Source : Central Marine Fisheries Research Institute) for 26 years ending 1994 (Annexure 2.1) which is used to forecast catch for 1995 is used for the formulation of this model (catch was taken in '000 tonne units and time t=1 for 1969). The initial values for $N_0$ and r are given as 91.363 and 0.172 respectively. The computer output of summary statistics is furnished below.

Table 2.1 : ANOVA : Malthus model

| Source | DF | SS | MS |
|---|---|---|---|
| Regression | 1 | 680167.89263 | 680167.89263 |
| Residual | 25 | 3939.35748 | 157.57430 |
| Uncorrected total | 26 | 684107.25011 | |
| Corrected total | 25 | 46228.69294 | |

$R^2$ = 1-Residual SS/ Corrected SS = 0.91479

Parameter r = 0.3850 with an asymptotic standard error of 0.000857, which proves the significance of r. Also, the lower and upper asymptotic confidence intervals are 0.03673 and 0.40268 respectively. F-value is highly significant ($p<.001$).

The regression explains more than 91 percentage of variation. Thus the model is a good fit and is given by

$N(t) = 91.3630 \times \exp(0.038502 \times t)$ ---------------------------(2.6.1)

Using this, the landings for next year can be predicted, by taking $t=27$. Thus, the forecast for 1995 is 263.63 ('000 t) whereas the actual value observed is 260.46 ('000t). The predicted value is deviated from actual only by 1.6 per cent. The closeness of forecast proves the reliability of the model.

The intrinsic growth rate r is +ve indicating that the present catch has not yet achieved the plateau stage.

***Malthus model - Kerala landings***

As presented in Annexure 2.2, the marine fish landings in Kerala have been behaving rather erratically over the years. Catch trend for the period 1976-87 showed a general decline. This dip in catch trend might have resulted in making modelling rather difficult. However, the result of the application of Malthus model to the fish catch data gives the nonlinear regression summary statistics as follows. (Table 2.2).

**Table 2.2 : Anova**

| Source | DF | SS | MS |
|---|---|---|---|
| Regression | 1 | 46334.98290 | 46334.9829 |

| | | | |
|---|---|---|---|
| Residual | 25 | 1966.30309 | 78.65212 |
| Uncorrected total | 26 | 48301.2860 | |
| Corrected total | 25 | 3319.36319 | |

$R^2$ = 1- Residual SS / Corrected SS = 0.40763

| Parameter | estimate | Asym. Std. Error | 95% Confidence limits lower | higher |
|---|---|---|---|---|
| r | 0.025916 | 0.00244 | 0.02088 | 0.03095 |

The model is

N(t) = 29.3 x exp(0.0259 x t) ------------------------------------(2.6.2)

The result shows that F and r values are highly significant. However, $R^2$ value is found to be only 40.8 percent. So the use of the model for prediction purpose is limited.

The model is further applied taking the dependent variable as the cumulative values of the annual catch. The summary statistics of the evaluation are given below in Table 2.3.

**Table 2.3 : Anova**

| Source | DF | SS | MS |
|---|---|---|---|
| Regression | 1 | 8004528.94840 | 8004528.9484 |
| Residual | 25 | 1095196.44985 | 43807.85799 |
| Uncorrected total | 26 | 9099725.39825 | |
| Corrected total | 25 | 2327561.15100 | |

$R^2$ = 0.52947

| Parameter | estimate | Asym. Std. Error | 95% Confidence Interval lower | higher |
|---|---|---|---|---|
| r | 0.15424 | 0.003465 | .14710 | .16138 |

As evidenced by the analysis the regression is highly significant, r=0.15424 with asymptotic standard error well within reasonable limits. Value of $R^2$ indicates that the regression explains 53.0 percent of the variance, a substantial improvement over the previous model.

Model is $N(t) = 29.3 \times \exp(0.15424 x t)$ ------------------------(2.6.3)

***Logistic model using prawn catch***

Of the total 5,31,646 tonnes of marine fish catch in Kerala during 1995, the contribution of Penaeid prawns amounted to 43,224 tonnes only. Inspite of a low percentage contribution in quantity, Penaeid prawn dominates other species in the fishery economy of the state due to its high unit value. The share of frozen prawns in the total export of marine products was 32.31 percent in terms of quantity and 67.32 percent in terms of value, during 1995-96.

As expected, the prawn catch also fluctuates over time, making modelling difficult. As the direct application of the growth models to the actual catch statistics was not found to yield good results, the modified data was used for modelling in the form of the cumulative values of the 3 year moving averages. An application of logistic model with initial values $K=1200$, $r=0.2$ and $N_0=33$, yields the evaluation summary as below. The NLR option in the SPSS/PC+ Ver.4.0 was used for the evaluation.

**Table 2.4 : Anova**

| Source | DF | SS | MS |
|---|---|---|---|
| Regression | 2 | 11759301.30780 | 5879650.65391 |
| Residual | 24 | 291668.98706 | 12152.87446 |
| Uncorrected total | 26 | 1205970.2949 | |
| Corrected total | 25 | 2839252.71874 | |

$R^2$ = 1-Residual SS/ Corrected SS = .89727

| Parameter | estimate | Asym. Std. Error |
|---|---|---|
| K | 1007.38580 | 48.11636 |
| r | 0.31193 | 0.01680 |

The parameter values K and r are highly significant ($p<.001$). The asymptotic 95% confidence interval is within reasonable limits, the lower and upper limits being 908.07850 and 1106.69309 respectively for parameter K. For parameter r the lower and upper limits were .27726 and .34659 respectively. The regression explains the variability as high as 89.727 percent. Hence the model is a very good fit.

The model is

$N(t) = 1007.38580/\{[1 + (K/No)-1] \exp(-0.31193\ t)\}$

$N(t) = 1007.3858/\{[1 + (1007.3858/33)-1]\exp(-0.31193t)\}$..(2.6.4)

***Application of the Gompertz model***

Gompertz model was applied to the same data and the result shows substantial improvement over the logistic model. The summary statistics give the following analysis. (Table 2.5)

**Table 2.5 : Anova**

| Source | DF | SS | MS |
|---|---|---|---|
| Regression | 2 | 11938908.3117 | 5969454.15587 |
| Residual | 24 | 112061.98316 | 4669.24930 |
| Total | 26 | 12050970.2949 | |

$R^2 = 0.96053$

The estimate of parameter K = 1216.63423 with an asymptotic standard error of 66.66335 and of r = 0.13240 with Asymptotic Standard Error = 0.00829.The regression explains 96 percent of the variability also. Hence the model is good fit and its improvement over logistic is 6.3 percent.

The model is

$N(t) = 1216.63423 \times \exp[(\ln(34/K)\exp(-.1324xt)]$

--------------(2.6.5)

***Non-mechanised sector - Bass model***

The mechanised and non-mechanised fishing sectors are complementary to each other in respect of fish catch.

The technological advancement over the years in the mechanised fishing sector has revolutionised the fishing industry. The share of the mechanised sector in the marine catch has gone up substantially over the years. Consequently, the traditional non-mechanised sector has considerably been reduced. Of the many models tried, the Bass model was found most suitable to describe the non-mechanised fishing sector in Kerala. Though the non-mechanised sector has registered a systematic decline, by taking cumulative catch as dependent variable, the model assumptions are satisfied.

Bass (1969) developed a model for adoption and diffusion of technological innovations, using time- series data. Jain *et.al*(1991) studied the diffusion of a new product or technology from its consumption pattern. In fisheries, except for the handling losses whatever is landed is consumed in fresh or processed forms. Thus consumption and production are to be treated as equal. The diffusion of mechanised fishing can be studied from the pattern of fish production in this sector. Since both the traditional and mechanised fishing are complementary, Bass model can be used for both. It is visualised that growth would ultimately slow down and saturate as the carrying capacity in any environment is limited. Bass assumed that initially a new technology is adopted by a few individuals in a limited way. He introduced in addition to density dependent growth, a growth which is a fraction of potential adopters.

Thus the model equation becomes

$dN/dt = [p + (q/m)N](M-N)$ -------------------------------------------(2.6.6)

where p is termed the external influence and q the internal influence in the conversion factor $[(p+q/m)N]$. M is the carrying capacity and N is the number of adopters at time t.

The above equation has a solution

$N(t) = M\left[(1-e^{-(p+q)t})/[1+(q/p)e^{-(p+q)t}]\right]$ ----------------(2.6.7)

The parameters p, q and M have been estimated using the following procedure.

We may write the relation (2.6.6) as

$N(t+1)-N(t) = [p+(q/M)N(t)][M-N(t)]$ -----------------------------(2.6.8)

or $N(t+1) = [p+(q/M)N(t)][M-N(t)] + N(t)$ -------------------(2.6.9)

The parameters are estimated using ordinary least square method, as suggested below.

$N(t+1)-N(t) = pM + N(t)(q-p) - (q/M)N^2(t)$

$= X + Y*N(t) + ZN^2(t)$ ------------------------------------------------(2.6.10)

where $X = pM$

$Y = q - p$

$Z = -(q/M)$ and $N(t)$ and $N(t+1)$ are the cumulative value at time t and $t_1$ so that $N(t+1)-N(t)$ becomes the given data. Since at $N(t) = M$, $N(t+1) - N(t) = 0$ and we can solve the equation (2.6.10) to get

$$M = [-Y - (Y^2-4XZ)^{1/2}]/2Z$$

Now, once M is known, p and q can be calculated.

Alternate procedure to estimate M, p, q using Nonlinear least square (NLS) is as follows.

Consider the equation

$$X(t) = M\left[\begin{matrix}\{1-\exp| \ -(p+q)t \ |\}/\{1+(q/p)\exp| \ -(p+q)t \ |\} - \\ \{1-\exp| \ -(p+q)(t-1)/\{1+(q/p)\exp| \ -(p+q)(t-1) \ |\end{matrix}\right] + U(t) \text{----}(2.6.11)$$

where u(t) is the error term and X(t) is the annual increment at time 't' which is the data itself.

Application of Bass model to the non-mechanised catch data for a period of 25 years ending 1995 gives the following results.

The initial values obtained by the above formulae are M = 450, p = 0.08, q = 0.12. The results of the analysis gives the summary statistics as below in Table 2.6.

**Table 2.6 : Anova for the Bass model**

| Source | DF | SS | MS |
|---|---|---|---|
| Regression | 3 | 2536494.01919 | 845498.00640 |
| Residual | 22 | 2527.01895 | 114.86450 |
| Uncorrected total | 25 | 2539021.03814 | |

| | | | |
|---|---|---|---|
| Corrected total | 24 | 340940.63569 | |

$R^2$ = 1-Residual SS/ Corrected SS = 0.99259

Estimates of parameters M, p and q are evaluated as

| Parameter | estimates | Asym. Std. Error | Asymptotic confidence interval (95%) | |
|---|---|---|---|---|
| M | 438.72734 | 13.39187 | 410.9543 | 466.500 |
| p | 0.11483 | 0.00699 | 0.10033 | .12933 |
| q | 0.01948 | 0.03123 | -0.04529 | 0.08424 |

Thus the model (2.6.7) becomes

$N(t) = 438.72734[\{1-e^{-(p+q)t}\} / \{1+(q/p)e^{-(p+q)t}\}]$ ------------ (2.6.12)

where p = 0.11483 and q = 0.01948 and t = 1, 2, ...... for the years 1971, 1972, ...... etc.

With $R^2$ = 0.9926, and the standard errors of the parameter estimates are well within reasonable limits, the model (2.6.12) is a best fit to the data. The model is estimated by using SPSS/PC + package. Using model (2.6.11), the values of M, p and q are estimated as M = 397.03988, p = 0.08590 and q = 0.08233. Substituting these values in (2.6.11) we get the alternative model.

## Reference


Bard, Y. (1974) *Non-linear Parameter Estimation*, Academic Press, New York and London.

Barlett, M.S. (1960) *Stochastic Population Model in Ecology and Epidemiology*. Methuen and company Ltd., London.

Bass, F.M. (1969). A new product growth model for consumer durables. *Manage. Sci.*. **15**, 215-227.

Bates, D.M. and Watts, D.G. (1980). Relative curvature measures of nonlinearity. *J. Roy. Statist. Soc.* **42**(1) **B**, 1-25.

Bates, D.M. and Watts, D.G. (1988). *Non-linear Regression Analysis and it's Applications*. John Wiley, New York.

Beale, E.M.L. (1960). Confidence regions in non-linear estimation. *J. Roy. Statist. Soc.* **22 B**, 41-76.

Bernhardt, I and Mackenzie, K.M. (1972). Some problems using diffusion models for new products. *Manage Sci.,* **19**, 187-200.

Bertalanffy, L. Von (1938). A Quantitative Theory of Organic Growth. *Hum. Biol.*, **10**(2), 181-213.

Beverton, R.J.H. and S.J. Holt (1957). On the dynamics of exploited fish populations. *Fishery Investigations*, H.M.S.O., London, 1957, **19** (11), 533pp.

Box, M.J. (1971). Bias in non-linear estimation, *J. R. Statist. Soc.,* , **42** (1) **B**, 1-25.

Chambers, J.M. (1973). Fitting non-linear models : numerical techniques. *Biometrika*, **60**, 1-13.

Clark, W.G. (1976). Dynamic pool models. In models for fish stock assessment. *FAO Fisheries Circular*, 701, 17-30.

Cornell, R.G. and J.A. Speckaman (1967). Estimation of a simple exponential model. *Biometrics*, **23**, 717-737.

Curry, H.B. (1944). The method of deepest descent for non-linear minimization problems. *Q. Appl. Math.*, **2**, 258-261.

Draper, N.R. and Smith, H (1966). *Applied Regression Analysis*. John Wiley, New York.

Draper, N.R. and Smith, H. (1981). *Applied Regression Analysis*. 2nd Edition, John Wiley, New York.

Foss, S.D. (1969). A method for obtaining initial estimates of the parameters in exponential curve fitting. *Biometrics*, **25**, 815-821.

Fox, W.W. Jr. (1970). An exponential Surplus yield model for optimising exploited fish populations. *Trans. Am. Fish. Soc.*, **99**(1), 80-88.

Gallant, A.R. (1987). *Non-linear Statistical Models*. John Wiley, New York.

Goldfeld, S.M. and R.E. Qiamdt. (1972). *Non-linear Methods in Economics*. Amsterdam : North Holland.

Hanumara, R.D. and Hoeing, N. (1987). An empirical comparison of a fit of linear and non-linear models for seasonal growth in fish. *Fish Res.* **5**, 359-381.

Hills, M (1969). A note on the analysis of growth curves. *Biometrics*, **24**, 189-196.

Hoeing, N. and Hanumara, R.C. (1982). A Statistical study of a seasonal growth model for fishes. Tech. Rep., Dept. of Computer Science and Statistics, University of Rhode Island. 99p.

Jain, A. Rai, L.P., Sharma, S. and Bhargava, S.C. (1991). Modelling Technology Diffusion. *J. Scientific and Industrial Research*, 50, 496-515.

Jenrich, R.I. (1969). Asymptotic properties of non-linear least squares estimators. *Ann. Math. Statist.*, **40**, 633-649.

Kualseth, T.O. (1985). Cautionary note about RV. *Am. Statist.*, **39**(2), 279-285.

Kurian, A. (1989). Application of Synthetic models for the assessment of Bombay duch Harpodon rehereus (Ham.) Stock off the Maharashtra coast, *Indian J. Fish.* **36**(4), 274-285.

Levenberg, K. (1944). A method for the solution of certain non-linear problems in least squares . *Quart. Appl. Maths.*, **2**, 164-168.

Mansfield, E. (1961). Technical change and the rate of imitation. *Econometrica*, **29**, 741-766.

Marquardt, D.W. (1963). An algorithm for least squares estimation of non-linear parameters. *J. Soc. Ind. Appl. Maths.*, **2**, 431-441.

Nair, K.R. (1954). The fitting of growth curves. *Statistics and Mathematics in Biology.* Iowa State College Press, Iowa.

Oliver, F.R. (1964). Methods of estimating the logistic growth function. *Appl. Statist.,* **13**, 57-66.

Oliver, F.R. (1970). Estimating the exponential growth function by direct least squares. *Appl. Statist.*, **19**, 92-100.

Pawlak, C and Hanumara, R.C. (1991). A comparison on nonlinear growth models for fisheries. *Fish. Res.* **11**, 143-154.

Ricker, W.E. (1946). Production and utilisation of fish population. *Ecol. Monogr.*, **16**, 374-391.

Robinson, B and Lakhani, C. (1975). Dynamic price models for new product planning. *Manage Sci.*, **21**, 1113-1122.

Ross. G.J.S. (1990). *Nonlinear Estimation*. Springer-Verlag, New York.

Schnute, J. (1981). A versatile growth model with statistically stable parameters. Can. J. fish. Aquat. Sci., **38**, 1128-1140.

Scott, A. and Wild, C. (1991). Transformation and R2. *The American Statistician*, **45(2)**, 127-128.

Smith, F.B. and D.F. Shanno (1971). An improved Masquardt Procedure for Nonlinear Regression. *Technometrics*, **13**, 63-74.

SPSS/PC+ 4.0 (1990). SPSS Inc. Chicago.

Stevens, W.L. (1951). Asymptotic regression. *Biometrics*, **7**, 247-267.

Wilson, A.L. and A.W. Douglas (1969). A note on non-linear curve fitting. *Am. Statist.*, **23**, 37-38.

# APPLICATION OF SYNTHETIC MODELS USING TIME SERIES CATCH - EFFORT DATA FOR FISHERY MANAGEMENT

G. Rajagopalan Unnithan "Stochastic models in fishery economics with special reference to Kerala " Thesis. Department of Statistics , University of Calicut, 1999

# CHAPTER3

CHAPTER 3

# APPLICATION OF SYNTHETIC MODELS USING TIME SERIES CATCH - EFFORT DATA FOR FISHERY MANAGEMENT

## 3.0 Introduction

The third UN Conference of the Law of the Sea 1982, created an Exclusive Economic Zone (EEZ) which extends upto 200 miles from the shore to the sea for all coastal countries. This has established the exclusive economic rights to these countries for conservation and exploitation of the resources in their respective zones. Accordingly, India has acquired an EEZ of 2.02 million square kilometers (Anon, 1993) of which Kerala coast accounts for about 0.19 million square kilometres.

Fisheries form one of the major resources in the EEZ for the economic development of Kerala with the quantity output of 5.68 lakh tonnes of fish (Anon, 1997) in 1996. Hence the fish stock assessment studies are vital for the conservation, management and rational utilization of fish stocks. A fish stock is defined as the part of fish population which is under consideration from the point of view of actual or potential utilization (Ricker, 1975). Gulland (1983) stated that the definition of a "unit stock" is an operational matter. This means that a subgroup of a species can be treated as a stock, if possible differences within the group and interchanges with other groups can be ignored without making the conclusion reached invalid (Sparre, P and S.C. Venema, 1992). According to them it is preferable to make stock assessments over the entire area of distribution of a species, as long as there is no indication that separate unit stocks exist in that area. An essential characteristic of a stock is that its growth and mortality parameters remain constant throughout its area of distribution. If we take two sub-areas of the area of distribution of a species the growth and mortality parameters may be the same. To avoid complexities, it is always safer to assume that species in the neighbouring areas form one unit stock as the fish stocks are not bound by human geographical limits. Fish stock assessment is mainly concerned with studying the effect of fishing on stocks and on catches for making appropriate fishery policy decisions. It is defined as "any scientific study to determine the productivity of a fishery resource and the impact of changing patterns of fishing" (Gulland, 1983). The basic objective of the fish stock assessment is to find the optimum exploitation level of the renewable fishery resources which gives the maximum fish catch in the long run so as to maintain balance between under utilization and over exploitation of the resources.

For studying the fish stocks and the effects of fishing on them, the relationship between the fishing effort, called the inputs and the fish landings, called the outputs should be well understood. Appropriate models which are quantitative descriptions of the real situations, are constructed for this purpose. Two main groups of models used in fish stock assessment are analytical models and holistic models, the former being age-structured models based on mortality and individual body growth rates, and the latter being models which consider a fish stock as a homogeneous biomass. A set of models used as a compromise between surplus production models and the age - structured models has been presented by Schnute (1985). But they have only limited use as they were developed for long lived (slow growing ) species and as such not suitable for prawn stocks. Some of the major contributions of fish stock assessment theories were developed by Barnov (1918) , Thompson and Bell (1934), Graham (1935), Beverton and Holt (1957), Schaefer (1954, 1957), Ricker (1954, 1975), Gulland (1983) and Pauly (1984).

One of the approaches in the holistic models *viz.* the stock production theory has led to the development of surplus production models which deal with the complete stock, total fishing effort and the total catch obtained from the stock. The surplus production models are also known as synthetic models in which we deal with only catch per unit effort, usually taken as boat days or trawling hours and catch (yield) as inputs. Basic assumptions related with these models are that the biomass of fish is proportional to the catch per unit effort and that the population is a unit stock which is in equilibrium

Fish stocks are affected by fishery dependent and fishery independent factors, the former include the level of effort, size of fleet etc. and the latter include environmental factors like salinity, temperature, moisture, humidity, water current etc. For unit stock assessments where equilibrium conditions are assumed, the fishery independent factors are safely ignored (Alagaraja, 1983). Classical models assume that the effects of fishery independent factors cancel in the long run or are assumed to be random fluctuations. Such category of models consist of deterministic models. The approach of incorporating random element in deterministic models leads to the concept of Stochastic models. Attempts have been made to include both fishery dependent and independent factors for yield (catch) forecasting in this chapter.

The surplus production models are used to determine the optimum level of effort that produces the maximum yield by weight that can be maintained indefinitely at a sustainable level. This yield is termed as the maximum sustainable yield (MSY) and the optimum effort level which in the long term gives the highest yield is indicated by $F_{msy}$.

Thus attempts have been made to estimate the MSY and $F_{msy}$ with regard to prawn fishery in Kerala, as the quantum of prawn catch is the decisive factor in the fishery economic growth of the state. Apart from identifying suitable models to describe the fish yield on effort levels, yield forecast is attempted using fishery independent factors, and the combination of the two. Study of the economics of operation of fishing boats also helps in fixing the optimum number of fishing boats that can be economically operated on the Kerala coast. The approach in this study concentrates on application of methods while less attention is paid to detailed explanation of theory behind them.

## 3.1 Limitations and significance of the study

The study targets only the prawn fishery of the Kerala state and the corresponding effort levels in terms of trawler fishing days. While considering the prawn catch from the mechanised sector as a whole, the prawn catch from trawlers and other mechanised vessels are clubbed together. The efforts expended for the mechanised sector are standardised with respect to trawler days. It also is to be borne in mind that the estimates of both MSY and $F_{msy}$ hold good only for an average situation as the distribution of catch and efforts are found to vary much from year to year.

Alagaraja (1984, 1990) described methods for estimation of parameters for assessing exploited fish stocks. Silas, et al. (1984) investigated the impact of effort on catch on the Kerala coast. Kalawar et al . (1985) studied the catch effort relationship of the prawn fishery from three major fishing centres of Kerala, viz,. Sakthikulangara – Neendakara, Cochin and Calicut and made separate estimates of MSY for these centres based on the limited data for the period 1970-80. Many developments have been taking place in the fishing activities over the years and the present study is based on the data covering a period of 20 years from 1976-96, thus including the latest trend in the prawn fishery exploitation and management in the state. Estimating MSY for sub-areas of the same geographical area may lead to erroneous conclusions. Hence prawn fishery in Kerala is considered as a single stock for the purpose of model formulation.

### 3.2 Catch effort models

Time series data on the prawn landings by both mechanised trawlers and the mechanised sector as a whole (including mechanised purseines, gill netters etc. ) along with the corresponding efforts collected systematically by the Central Marine Fisheries Research Institute (CMFRI), Cochin, based on a multistage stratified random sampling procedure (Banerji, 1971), forms the data base of this study. The catch per unit effort (CPUE) based on annual catch & effort data on the Kerala coast was worked out for a period of 20 years from 1976-96 (Source : Central Marine Fisheries Research Institute, Cochin).

***Schaefer's model***

In the Schaefer model, catch (in weight) per unit effort (Y/f) and effort f (boat days or trawling hours) are the input data, and Y/f is a monotonically decreasing function of f. The model is

$$(Y/f) = a - bf \text{ ---------------------------------------------- } (3.2.1)$$

where a and b are constants. The slope, b is negative as Y/f decreases with increasing effort f. The intercept a is the Y/f value when $f \rightarrow 0$ or when the first boat fishes on the stock.

The absolute yield Y is given by

$$Y = af - bf^2 \text{ ---------------------------------------------- } (3.2.2)$$

The MSY is estimated by the equation

$$MSY = a^2 /4b \text{ ---------------------------------------------- } (3.2.3)$$

$$\text{and } f_{msy} = a/2b \text{ ---------------------------------------------- } (3.2.4)$$

where $f_{msy}$ is the effort required to harvest the msy.

***Fox model***

Fox (1970) introduced an alternative model

$$Y/f = a \exp(-bf) \text{ ---------------------------------------------- } (3.2.5)$$

$$\text{or } \log_e(Y/f) = c + df \text{ ---------------------------------------------- } (3.2.6)$$

where $\log_e(Y/f)$ is plotted against effort f.

Model (3.2.6) can be written as

$$Y/f = \exp(c+df). \quad \text{------------------------------------------------} (3.2.7)$$

which approaches zero only at very high f values. Thus Fox model becomes important when large f values are reached.

For the Fox model,

$$MSY = (1/d) \exp(c-1) \quad \text{------------------------------------------------} (3.2.8)$$ and

$$fmsy = 1/d \quad \text{------------------------------------------------------------} (3.2.9)$$

and $$Y = f \exp(c+df) \quad \text{------------------------------------------------} (3.2.10)$$

we can draw yield curves using (3.2.2) and (3.2.10).

***Application of Schaefer model***

Time series data for catch per unit effort Y/f (in Kilogram) and fishing effort f (in number of boat trips) for the period 1970-96 (Source : Central Marine Fisheries Research Institute, Cochin) were fitted to Schaefer model. The fitted model becomes

$$Y/f = 204.38064 - 0.000238 f \quad \text{------------------------------------------} (3.2.11)$$

The regression was found to be highly significant with F=11.05 (sig. at .0027) and both a and b coefficients also were highly significant (sig. t=.0000 and .0027 respectively).

Now, using the relations (3.2.3) and (3.2.4), the MSY for the prawn stocks has been estimated at 43,857 tonnes for an estimated optimum effort $f_{msy}$ of 4,29,350 boat trips per year.

***Application of Fox model***

The application of Fox exponential model (3.2.5) to the catch-effort data has brought out the relation of the form, Ln (Y/f) = c-df ------------------------------------------------------------(3.2.12)

where c is the constant term and d is the coefficient of the variable f. From the regression analysis, we substitute values for c and d and the model becomes

Ln (Y/f) = 5.26771 - 0.00000182 f ----------------------------(3.2.13)

or Y/f = exp[5.26771-0.00000182f] --------------------------(3.2.14)

The regression is highly significant with F=18.04 (sig. F= .0003) and also both a and b coefficients are highly significant (significant at .0000 and .0003 respectively). Now, using the relations (3.2.7) and (3.2.9), the MSY is estimated at 39,208 tonnes and the $f_{msy}$ value at 5,49,451 boat days.

The details of the two models are summarised as below :

**Table.3.1.: Comparison between models**

| | Shaefer | Fox |
|---|---|---|
| a | 204.38064 | 5.26771 |
| b | -2.38011E-04 | -1.81906E-06 |
| SE(a) | 31.20573 | 0.18670 |
| SE(b) | 7.15927 | 4.28326E-07 |
| $R^2$ | 0.30657 | 0.41909 |
| Beta | -0.55368 | -0.64738 |
| F-value for regression | 11.05242 | 18.03629 |
| MSY (Tonnes) | 43857 | 39208 |
| $f_{msy}$ (boat trips) | 429350 | 549451 |

The relation (3.2.11) of Y/f on f gives a straight line where for the effort f tend to zero, the CPUE Y/f is the maximum and so is the biomass

(B) since Y/f = qxB where q is the catchability coefficient which is a constant. Thus the biomass B corresponding to f=0 becomes the unexploited stock which is also called the `virgin stock biomass' (Bv). In the case of Shaefer model,

qxBv = a=204.38064.

The relation (3.2.14) of Y/f on f is a curve which approaches zero only at a very high level of effort, but never actually touches the zero mark. Thus in the case of Fox model,

qxBv = exp (c) = exp (5.26771).

The surplus production models are quite popular for its simplicity as evidenced in the above relations. At the same time, they are based on certain assumptions. One of them is the assumption of an equilibrium situation. In such a situation, the production of biomass in unit time equals the total fish mortality in unit time, which includes the fishing mortality and natural mortality. Ricker (1975) explained that the efficiency of reproduction is reduced at near maximum stock density and also the recruitment will increase at the reduction of the stock, which is a biological assumption. Another assumption is that the fishing mortality is proportional to effort and catch per unit effort is a monotonically decreasing function of effort. The fishing efforts considered in the study are assumed to be standardised in terms of boat type, trawling time, type of fishing etc.

Some of the aspects of the model applications which are to be borne in mind are the fishing technological development over years and the stock. The efficiency and size of boats might have changed over long years of time due to the technological development. Thus the rate of mortality caused by boat trips might have increased over years affecting the catchability coefficient q which is assumed to be constant. Thus it would be better not to include too long period of time series data for the model building. `Stock' term is usually applied to one species having the same growth parameters and inhabiting in a particular geographical area. We can make separate stock estimates for neighbouring areas only if there is no mixing of the stocks between these areas or that they are independent.

The fishing trawler efforts increased at a slow pace from 2,43,000 boat trips in 1970 to reach 3,00,000 trips in 1982, but suddenly it jumped to 3,93,000 in 1983 and shot upto 7,24,000 in 1994 and came down to around 5,00,000 in 1995 and 1996. Owing to increased fishing pressure, the catch per unit effort is reduced to 61 tonnes in 1995 and 65 tonnes in 1996. The average number of fishing trips per annum per boat during 1980-81 was 157 (John Kerien and Rolf Willmann, 1982) and the maximum of 215 days a year (Bhaskaran Pillai, 1980). The present study shows that during 1990-96, the average trawler trips expended was 562,714 and the average number of fishing trips was around 185 days only. Thus even though the number of mechanised fishing units touched the average level of 3850 in 1991 - 95 (of which 80% are trawlers) the fishing trips per boat continue to be around 185 only. This may be partly due to economic pressure and partly due to trawl ban during monsoon season for 45 days in Kerala. Hence fishing pressure appears to be due to the increase in the number of trawlers rather than the number of fishing trips per trawler. More number of trawlers are introduced to operate mainly in the peak fishing seasons. This may be the reason for the number of trawler trips to cluster around 185 only in a year.

As the Schaefer model suggests, the MSY can be harvested with an optimum effort level of 4,29,350. If we take the average fishing days a year to be 215, the optimum number of trawler units required for the Kerala coast is 1997. Further Schaefer model tells that MSY level was crossed in 1994 (62,096 tonnes) by the trawlers resulting in reduced catches in the next two years (31,000 tonnes each). The present level of effort also was higher than the $f_{msy}$ suggesting an increased pressure on fishing.

According to Fox model also, the MSY level (about 40,000 tonnes) was crossed in 1994, resulting in less trawler catch in the subsequent years. However, the $f_{msy}$ is 5,49,451 and the optimum number of trawlers at the rate of 215 boat trips per year is 2556. The average number of boat trips during 1990-95 (56,300 trips) suggest that the present level of exploitation is higher than the $f_{msy}$. Hence suitable management measures are recommended to reduce the trawling pressure for the sustainable growth of the fishing industry.

**3.3 Total prawn catch and standardised effort**

We have dealt with prawn catch by trawler and the corresponding effort in the previous section to estimate the maximum sustainable yield which can be harvested by trawlers. But it is to be noted that gears other than trawl also catch a substantial quantity of prawns, though the target species is not prawn. The average trawl catch of prawns (1987-96) works out to 41,011 tonnes whereas the prawn catch by all gears is estimated on an average at 53,977 tonnes based on the same period. Thus the nontrawl gears contribute 24% of the total prawn landings in this state. Efforts expended by nontrawls are not comparable with trawler efforts. Accounting for the nontrawl gear efforts poses a serious problem. One way of solving this, is to standardise the efforts expended for prawn catch in terms of trawl efforts.

Considering the relation f=Y/CPUE, we assume that CPUE for prawn catch by trawlers is the same for the prawn catch by all gears taken together. Thus by dividing the total prawn catch of an year by the corresponding CPUE of trawlers, we get the standardised effort of that year. Plotting CPUE (in kgs) against standardised effort for 1970-96 and fitting the Schaefer model, the relation becomes

$Y^*/f^* = 202.02517 - 0.000179 f^*$.------------------------------(3.3.1)

where $Y^*$ denotes the prawn catch by all gears and

$f^*$ denotes the standardised effort expended.

The regression analysis gives F=12.01, sig at 0.0019; $R^2=0.3245$ and Beta = - 0.57. Both a and b coefficients are also highly significant (sig t = 0.0000 and 0.0019 respectively). Thus the model is a good fit.

The MSY for the prawn stock is worked out at 57,350 tonnes with an $f_{msy}$ value of 5,67,754 fishing effort. Thus the maximum sustainable prawn yield in Kerala which can be harvested by all gears is 57,350 tonnes by an optimum effort equivalent to 5,67,754. Depending on the earlier assumption of 215 fishing trips by trawlers in an year, 2641 trawlers will be optimum number of the trawl fleet. Since prawn catch by nontrawl gears cannot be restricted, our interest is now concentrated only in MSY figures based on standard efforts. As stated earlier, the average prawn harvest(1987-97) is around 54,000 tonnes. This is indicative of the fact that Kerala has almost reached the MSY level of prawn stocks. Infact this level was crossed three times during the last ten years. These estimates again call for suitable prawn conservation measures.

The application of Fox model to CPUE against standard effort gives the relation,

$Ln(Y^*/f^*) = 5.26597 - 0.00000139 f^*$ ------------------------(3.3.2)

where * indicates that values are based on standardised efforts. $R^2$ = 0.4643 and the regression is highly significant (sigF=0.0001). Both c and d coefficients also are highly significant and Beta is -0.6814.

The MSY value for the prawn stock to be harvested by all gears is worked out using Fox model as 51,212 tonnes with an $f_{msy}$ of 7 lakhs. Thus the present average level of exploitation of 54,000 tonnes per year is at a higher level. Estimates of MSY values based on both models gives similar results. This finding also emphasises the existence of high fishing pressure on the prawn stocks of Kerala.

### 3.4 Yield models

From the Schaefer model given by

Y/f = a-bf, we are guided to the result that the absolute yield Y is parabolic function of f. Thus we get,

$Y = af - bf^2$ ----------------------------------------------------------------(3.4.1)

In the fox model, Y/f = a exp (-bf),

$Ln(Y/f) = c - df$ or $Y/f = e^{(c-df)}$

$$\therefore Y = \left[ e^{c} . e^{-df} \right] f \qquad \text{------------------------------------------(3.4.2)}$$

Substituting for a and b, equation (3.4.1) becomes

$Y = 204.38064 - 0.000238 f^2$ ------------------------------------------ (3.4.3)

Similarly, substituting for c and d, equation (3.4.2) becomes

$$Y = \left[ e^{5.26771} . e^{-0.00000182 * f} \right] f$$

$$= e^{5.26771} . f . e^{(-0.00000182 * f)}$$

$$= 193.37126 f [\exp(-0.00000182 f)] \qquad \text{------------(3.4.4)}$$

***Application of Hyperbolic and Power models***

Two other models, Hyperbolic and power models also are attempted here for fitting yield curves.

Hyperbolic model considered here is of the form,

$Y/f = 1/(a+bf)$ ------------------------------------------------------------(3.4.5)

or $1/(Y/f) = (a+bf)$ ----------------------------------------------------(3.4.6)

where a and b are evaluated by regressing the reciprocal of Y/f with effort f.

The regression results in $R^2$ value of 0.45457

with F = 20.83523 (significance of F = .0001) a = 0.00503, SE = 0.00162, t = 3.099(sigt =0.0048)

b = 1.69858 $E_{08}$, SE = 3.72124E-09, t = 4.565; sigt = 0.0001

Beta = 0.67422

The yield curve in respect of hyperbolic relationship is given by

Y = f/ a+bf ------------------------------------------------------------(3.4.7)

Finally, the power relationship is given by,

$Y/f = af^{-b}$ ----------------------------------------------------------------(3.4.8)

Taking logarithms on both sides, equation (3.4.8) becomes

Ln(Y/f) = Ln(a) - bLn($f$)

= c-dLn($f$)----------------------------------------------(3.4.9)

Regression results in $R^2$=0.53867, F=29.19133, Sig F= 0.0000

c = 14.97659, SE=1.9320, t=7.752, Sig t = 0.0000

d = -0.81550, SE = 0.15094, t = -5.403, Sig t = 0.0000

Beta = -0.7340

The yield model in respect of power relationship is expressed by,

$Y = a.f^{-b}.f$

or $Y = a.f^{(1-b)}$ ---------------------------------------------------------(3.4.10)

Thus, the fitted models between Y/f and f are,

Schaefer : $Y/f$ = 204.38064 - 0.000238$f$ ----------------(3.4.11)

Fox : $Y/f$ = 193.97126 exp(-0.00000182$f$)-------(3.4.12)

Hyperbolic : $Y/f$ = 1/(0.00503+1.69858E-08$f$) ------------(3.4.13)

Power : $Y/f = 3193378f^{0.8155}$ ---------------------------(3.4.14)

The yield models are

Schaefer : $Y = af - bf^2$

Fox : $Y = af \exp(-bf)$

Hyperbolic : $Y = f / (a + bf)$

Power : $Y = af^{(1-b)}$

All these models give highly significant F-values for the regressions as described above. The $R^2$ and Beta values of the models are presented in a nutshell as below .

| Model | $R^2$ | F-value | Beta |
|---|---|---|---|
| Schaefer | 0.31 | 11.05 | 0.55 |
| Fox | 0.42 | 18.04 | 0.65 |
| Hyperbolic | 0.46 | 20.84 | 0.67 |
| Power | 0.54 | 29.19 | 0.73 |

Thus, the yield (in tonnes) for the above relationships observed are

Schaefer : $Y = 204.38064 f - 0.000238 f^2$ ---------------(3.4.15)

Fox : $Y = 193.97126 f [\exp(-0.00000182 f]$ ------(3.4.16)

Hyperbolic : $Y = f / (0.00503 + 1.69858E\text{-}08 f)$ --------------(3.4.17)

Power : $Y = 3193378 f^{-0.8155}$ -----------------------------(3.4.18)

### 3.5 Discussion

The statistical criteria used for the evaluation of models (3.4.11) to (3.4.14) were the $R^2$ and beta values. The best fit is obtained with the linear transformation of power relationship which gives the highest $R^2$ and beta values 0.54 and 0.73 respectively. The other forms also are found to fit data well, but only with less $R^2$ and beta values. The highest $R^2$ value for power form was followed by hyperbolic (0.46), Fox (0.42) and Schaefer (0.31) with beta values 0.67, 0.65 and 0.55 respectively.

For an optimum effort of 243000 the maximum yield worked out are as follows.

Schaefer = Y 204.38064 f – 14053662 kgs = 35611 (tonnes)

Fox Y/af = exp (-0.00000185 x *f* )

= exp(-0.00000185x 243000) for >0

= exp(-0.44226)

= $(1.55622)^{-1}$

= 0.64258

Fox Y = 30288 tonnes

Hyperbolic Y = *f*/0.00503+0.00413

= *f*/0.00916

= (243000/0.00916)/1000

= 26528(tonnes)

Power Y = 3193378 x 9.85472 kgs

= 31469 (tonnes)

Thus the yield estimation using Schaefer's, Fox, Hyperbolic and Power models give similar results.

### 3.6 Economics of operation of fishing trawlers

Mechanisation of fishing boats played a dominant role in the overall development of the fisheries sector in Kerala. Since the introduction of mechanised boats in the fifties (50's) major technological changes had taken place in the fishing field and the spread of the innovations led to rapid mechanisation of the fishing fleets . From a meagre number of about a dozen mechanised boats operated in Kerala during 1957, there were about 2900 mechanised boats in 1980, of which 84% were trawlers (Iyer *et. al*, 1985). Consequent on the increase of trawlers over years, the number of mechanised boats was reported to be 4206 (Anon, 1997) in 1995-96. The return over capital showed a decreasing trend over the years mainly due to declining catch per trawler and the soaring cost of operations. The trawlers were reported to be operating within 70 m depth only, sharing almost the same resources. Planners and fishery experts demanded periodic study on the economics of operation of trawlers with a view to fix the optimum number of fishing trawlers suitable for a viable fishing industry in Kerala. With this background, this study was undertaken to assess the economic performance of trawlers and to recommend the optimum number of trawlers for the Kerala coast based on the primary data collected from the fisheries harbour, Cochin.

**Materials and methods**

Data on the economics of mechanised trawlers were collected from Cochin fisheries harbour, one of the premier trawler landing centres of Kerala, during 1995. Using a systematic random sampling technique, data were collected from randomly drawn 10 trawl units per day for 10 selected days a month.

The data on capital investment including cost of hull, engine, gears and accessories, interest on capital insurance etc. were collected for working out the fixed cost. On the variable cost side, the fuel cost, wages and commissions, cost of repair and maintenance, cost of ice, food and bata to the crew and other incidental expenses were collected. Details on the catch and revenue aspects, sales proceeds etc. also were collected from each sampled trawler, apart from details of crew, depth of operation and duration of fishing trips.

The capital cost involved per trawler, was worked out taking into account the depreciation on hull and engine, gears and accessories. The depreciation for hull and engine was 10%, while the gears (about six nets per trawler) were observed to be replaced in every two years. The accessories were reported to have a life of 3 years. The interest on capital was at the rate of 18% and the insurance rate was 5% of the capital. The number of working days for a trawl unit was taken as 250 fishing days a year.

The trawlers were observed to operate at a depth of 50-70 metres and the duration of fishing (including time taken for reaching the fishing ground and return) ranged from 10 to 17 hours. It is estimated that about 200 litres of fuel is consumed for a trip of 15 fishing hours a day. The crew consisted of 6 persons on an average, who were paid bata of Rs.300/- per day and the daily crew wages was worked out as one third of the total revenue minus the actual operational expenses on a day. Repair and maintenance cost averaged Rs.250/- per fishing day.

The fish landed at the harbour was sold by auction and the selling price varied between seasons and even between days. So, for calculating the total revenue, the beach price estimated by the department of fisheries, Govt. of Kerala was taken as the standard. The beach price for

Prawns, fish and cephalopods were Rs.40,000, Rs.10,000 and Rs.12,000/- respectively per tonne.

The net annual profit is the difference between the gross revenue, and the fixed and the variable cost. Other economic indicators like the rate of return to capital, pay back period, revenue per man day, fish production per litre of fuel etc. also are worked out.

**Results and discussions**

***Capital investment***

The capital consists of Hull and engine, gears and the accessories. The cost of Hull and engine has been estimated as Rs.5.00 lakhs and the gears and accessories for a trawl unit have been valued at Rs.0.90 and 0.60 lakhs respectively, thus making the total investments at Rs.6.50 lakhs. The depreciation for the trawler is taken as 10% and the life of gears (normally 6 nets) and accessories are taken as 2 and 3 years respectively. Taking account of the rate of depreciation, the annual fixed cost per trawler unit is furnished in table 3.2.

**Table 3.2:Annual fixed cost of a trawl unit during 1995**

| No. | ITEMS | COST (Rs.) |
|---|---|---|
| (a) | Hull and Engine | 50,000 |
| (b) | Gears | 45,000 |
| (c) | Accessories | 20,000 |
| (d) | Interest on C.I. (@18%) | 1,17,000 |
| (e) | Insurance (@5%) | 32,500 |
| | Total annual fixed cost | 2,65,000 |

| | | |
|---|---|---|
| | Fixed cost/trip @ 225 fishing days a year (Rs) | 1178 |

Thus the total fixed cost per trawler during an year has been calculated at Rs.2,65,000. On the basis of 225 fishing trips an year, the share of fixed cost works out at Rs.1178 per fishing day.

***Operational Cost***

The operational cost or the variable cost is the cost incurred for operating a trawler. The main components are the crew wages, fuel cost, auction charges, bata to crew, repair and maintenance cost, cost of ice and other miscellaneous expenses. Apart from fuel cost, wages and miscellaneous expenses, auction charge is rated at 5% of the sale proceeds or the gross return. So the auction charges highly fluctuate depending on the sales per trip. Cost of ice depends on the weather and the fishing time. The crew wages also depend on catch as it is fixed as one third of the net revenue. Thus the crew wage is found to vary between fishing trips. The components of variable cost, and the revenue per fishing trip during the period of study is presented (month-wise) in the following table.

## Table 3.3 : Operational cost of trawlers per fishing trip (Rs.)

| Month | Revenue | Fuel cost | Bata | Agents commission | Cost of Ice | Crew wages | Repair of maint. | Misc. | Total operational cost |
|---|---|---|---|---|---|---|---|---|---|
| Jan '95 | 4421 | 1520 | 300 | 221 | 75 | 806 | 250 | 150 | 3322 |
| Feb | 5063 | 1050 | 300 | 253 | 60 | 1154 | 250 | 150 | 3217 |
| March | 5034 | 1520 | 300 | 252 | 75 | 997 | 250 | 150 | 3544 |
| April | 6655 | 1400 | 300 | 333 | 60 | 1666 | 250 | 150 | 4159 |
| May | 9266 | 1800 | 300 | 463 | 75 | 2399 | 250 | 150 | 5437 |
| June | 17306 | 1800 | 300 | 865 | 75 | 5039 | 250 | 150 | 8479 |
| August | 10217 | 1800 | 300 | 511 | 75 | 2536 | 250 | 150 | 5622 |
| September | 10064 | 1890 | 300 | 503 | 60 | 2453 | 250 | 150 | 5606 |
| October | 5668 | 1600 | 300 | 283 | 75 | 1175 | 250 | 150 | 3833 |
| November | 4507 | 1550 | 300 | 225 | 60 | 835 | 250 | 150 | 3370 |
| December | 5993 | 1650 | 300 | 300 | 60 | 1272 | 250 | 150 | 3962 |
| Total | 84194 | 17580 | 3300 | 4207 | 750 | 20332 | 2750 | 1650 | |
| Average | 7654 | 1598 | 300 | 382 | 66 | 1848 | 250 | 150 | 4597 |
| % of Op. cost | -- | 34.8 | 6.5 | 8.3 | 1.5 | 40.2 | 5.4 | 3.3 | |

Thus it is observed that the crew share and fuel expenses constitute the major share (75%) in the variable cost with the crew share and fuel expenses being 40.2 and 34.8 percentages respectively. The auction charge (Agents' Commission) comes to 8.3%, bata to crew is 6.5%, and repair and maintainance is 5.4 percent.

The variable cost is observed to vary between months. It may be seen that the variable cost sharply increases during May-September. This is mainly due to the fact that the returns from the catch is high during this period and consequently, the auction charges and the crew wages also increased. The increase in fuel cost is indicative of the fact that the fishing time is more during this period.

The annual variable cost comes to Rs. 10.34 lakhs per trawler based on 250 fishing trips in a year. The 6 member crew is paid as high as Rs.4.16 lakhs or daily wage amounts to an average of Rs.308 per fisherman. The variable cost per trip based on 225 fishing days a year comes to Rs.4597.

***Revenue and profit***

The gross annual revenue is worked out at Rs. 17.22 lakhs. Revenue per trip is maximum during May to September. This is due to high catch of prawns which fetches high unit price.

Net operating profit is the difference between gross revenue and operating cost. The net operating income from fishing trips is worked out at Rs. 3057. The net operating profit is minimum (Rs.1099) in January and maximum in June (Rs. 8827). The net operating profit is high during May to October varying from Rs. 3833 to Rs. 8827. This amount is shared by share holders of the boat. The table 3.4 below shows the economic analysis in a nut shell.

**Table 3.4 : Result of economic analysis**

| | | |
|---|---|---|
| i. | Annual fixed cost (lakhs Rs.) | 2.65 |
| ii. | Annual variable cost (,,) | 10.34 |
| iii. | Fixed cost + variable cost (,,) | 12.99 |
| iv. | Operating profit (,,) | 6.88 |
| v. | Net annual profit (,,) | 3.46 |
| vi. | Annual profit (percentage) | 26.64 |
| vii. | Pay back period (years) | 3.75 |
| viii. | Fish production per man day (kg) | 85 |
| ix. | Fish production per litre fuel (kg) | 2.55 |
| x. | Net revenue per litre fuel(Rs.) | 15.28 |

## Conclusion

The summary of the economic aspects of fishing in the Cochin fisheries harbour is given in the above table. The result shows that trawling is profitable to the tune of 26.65 percent per year. Eventhough the capital investment is high, the pay back period shows that capital is recoverable in less than four years. Fishermen also are highly benefited from the trawling operation.

## Reference


Alagaraja, K. (1983). Mathematical models in fish stock assessment. *J. Mar. Biol. Ass. India*, **25(1 & 2)**; 142 – 157.

Alagaraja, K. (1984). Simple methods for estimation of parameters for assessing exploited fish stocks. *Indian J. Fish.*, 31, 177-208.

Alagaraja, K. (1990). Fisheries resources assessment – a glance. *Industrial Fisheries Association Annual.* **7**, 5-11.

Anon. (1982). Trends in marine fish production in India – 1981. *Mar. Fish. Infor. Serv. T & E Ser. CMFRI*, No.(41), 1-33.

Anon. (1994). *Hand Book on Fisheries Statistics, 1993.* Ministry of Agriculture, Govt. of India.

Anon. (1997). Marine Fisheries of Kerala at a Glance, *Fisheries at a Glance 1996*, Govt. of Kerala.

Banerji, S.K. (1971). *Fishery Statistics.* Food and Agricultural Organisation of the United Nations. Publ. No.FC/DEV/71/5: pp15.

Berverton, R.J.H. (1954). Notes on the use of theoretical models in the study of dynamics of exploited fish population, Misc. Contrib. No.2 Fishery Lab., Beanfort, N. Car. (Mimeo).

Berverton, R.J.H. and S.J. Holt. (1957). On the dynamics of exploited fish populations. *Fishery Investigations*, H.M.S.O., London, 1957, **19**(11), pp533.

Chakraborthy, (1973). An evaluation of marine fish resources of India *Proc. Symp. Living Seas around India.* Living expansion & Cochin, CMFRI, 229-243.

Fox, W.W. Jr. (1970). An exponential surplus yield model for optimising exploited fish population. *Trans. Am. Fish. Soc.*, 99(1), 80-88.

George, M.J., Suseelan C., Thomas, M.M. and Kurup, N.S, (1980). A Case of over fishing: Depletion of shrimp resources along Neendakara coast of Kerala. Mar. Fish. Infor. Serv. T & E Ser., (18), 1-7.

Graham, M. (1935). Modern theory of exploiting a fishery and applications to north sea trawling. J. Cons. CIEM,10, 264-274.

Gulland, J.A. (1969). *Manual of Methods of Fish Stock Assessment.* Part I Fish population analysis. FAO Man. Fish. Sci., (4), pp.154.

Gulland, J.A. (1983). *Fish Stock Assessment. A Manual of Basic Methods.* Chichester, U.K., Wiley Interscience, FAO/Wiley Series on Food and Agriculture, Vol. 1, pp.223.

Gulland, J.A. (1983). *Stock Assessment: Why?* FAO Fish Circ. 759, pp.18.

Gulland, J.A. (1983a). *Fish Stock Assessment. A Manual of Basic Methods*. Chichester, U.K., Wiley Interscience, FAO/Wiley Series on Food and Agriculture, Vol. 1, 1 - 223.

Iyer, H.K., Unnithan, G.R., Rao, P.S. and Nair, A.K.K. (1985). *Harvest and Post harvest Technology of Fish* (Ravindran, K. et al., Eds.) pp.721, SOFTI, Cochin.

Kalawar, A.G., Devaraj, M and Parulekar, A. H. (1985). *Report of the Expert Committee on Marine Fisheries in Kerala*. Submitted to Govt. of Kerala.

Pauly, D. (1979). Theory and management of tropical multi -species of stocks : a review with emphasis on the South-East Asian demersal fisheries. ICLAM Stud. Rev., (1), pp.35.

Ricker, W.E. (1954). Stock and recruitment. *J. Fish Res. Board Can.* **11**, 559-623.

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish populations. *Bull. Fish Res. Board Can.* No191, pp. 382.

Schaefer, M. (1954). Some aspects of the dynamics of fish populations important to the management of the commercial marine fisheries. Bull. I-ATTC/Bol.CIAT, **1**(2), 27-56.

Schaefer, M. (1957). A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bull. I-ATTC,2(6), 247-285.

Schnute, J. (1981). A versatile growth model with statistically stable parameters. Can. *J. Fish Aquat. Sci.*, **38**, 1128-1140.

Schnute, J. (1985). A general theory for analysis of catch and effort data. *Can. J. Fish Aquat. Sci.*, **42**, 414-29.

Silas, E.G., Goerge, M.J. and Jacob, T. (1984). A review of the shrimp fisheries of India, a scientific basis for the management of the resources. In: *Penaeid Shrimps – Their Biology and Management*, Fishing New books Limited, (Gulland, J,A, and Rothschild, B.J., Eds) 83-103.

Sparre, P., Venema, S.C. (1992). *Introduction to Tropical Fish Stock Assessment.* Part I Manual. FAO Fisheries Technical Paper No. 3601, Rev. 1. Rome, FAO. 1992, pp.376.

# EFFECT OF ENVIRONMENTAL FACTORS ON MARINE FISH CATCH OFF KERALA COAST

G. Rajagopalan Unnithan “Stochastic models in fishery economics with special reference to Kerala ” Thesis. Department of Statistics , University of Calicut, 1999

# CHAPTER 4

# EFFECT OF ENVIRONMENTAL FACTORS ON MARINE FISH CATCH OFF KERALA COAST

## 4.0 Introduction

Fishes are known to be very sensitive to their environments.They are continuously in search of living environments for food, growth and reproduction and they move in shoals from one area in the sea to another. Marine fish catch, as such depends on technological changes which include modern fishing methods, vessels, trained manpower etc. At the same time, catch depends on the availability of fish stocks in the fishing ground. Unless fish shoals are in plenty, fishing activity will result only in wasteful or uneconomic exercise.

The environmental factors, particularly the weather variables play an important role in the migration and recruitment of fish. Thus the identification of weather parameters and their impact on the catch becomes a major area of fishery research. Kalawar Committee (1985) suggested an in depth study on these lines on the Kerala coast.

In the present study, the effect of the environmental variables *viz.* rainfall, maximum temperature, minimum temperature, humidity, etc. on the fish catch are probed using secondary time series data, based on the application of statistical models.

The approach to this chapter is based on the assumption that the influence, if any, of the weather on fish catch depends not only on the magnitude, but also, the distribution pattern of the variables over the fishing season. Thus, values of n different variables or values of the same variable in n different time intervals, or a combination of the two was considered for the study.

### 4.1 Models in use

We denote the fish catch, the dependent variable, by Y and the n weather variables or values of the same variable in n different times or a combination of the two by X1, X2, ........, Xn.

An application of the multiple regression model gives the form

$$Y = A_0 + A_1X_1 + A_2X_2 + \dots A_nX_n \text{ ----------------------------------------(4.1.1)}$$

This may require estimation of a large number of constants for which a long series of data may be required and in many situations this may not be feasible. In Agriculture experiments, Fisher (1924) assumed that effects of change in weather variables in successive periods of time would not be abrupt, but an orderly one that follows some mathematical law. He modelled these effects as terms of a polynomial function of time.

$$A_w = a_0[f_0(w)] + a_1[f_1(w)] + a_2[f_2(w)] + \text{ -- } + a_k[f_k(w)] + . \text{-----(4.1.2)}$$

where $A_w$ is the effect of unit change in weather variable on yield in the wth week (w=1,2,3,....,n), $a_0, a_1, a_2, \dots a_k$ are constants to be determined. The function $f_i(w)$ is orthogonal polynomial of the $i^{th}$ degree ($i = 0,1,2,...,k$)

Further, $X_w$ was also expressed in terms of orthogonal functions of time,

$$Xw = \rho_0[f_0(w)] + \rho_1[f_1(w)] + \rho_2[f_2(w)] + ..... + \rho_k[f_k(w)] + \text{ --------(4.1.3)}$$

where $\rho_i$ are distribution constants of $X_w$.

Substituting the expression for $A_w$ and $X_w$ in equation (4.1.1) and utilising the properties of orthogonal and normalised functions f(w) he obtained

$$Y = A_0 + a_0\rho_0 + a_1\rho_1 + a_2\rho_2 ...... + a_k\rho_k + ... \text{--------------------------(4.1.4)}$$

Hendricks and Scholl (1943) modified Fisher's technique. The season was divided into n weekly intervals and a second degree polynomial in week number was fitted to express the relationship as

$$A_w = a_0 + a_1 w + a_2 w^2 \qquad \text{where}$$

$$A_1 = a_0 + 1.a_1 + 1^2.a_2$$

$$\vdots$$

$$\vdots$$

$$An = a_0 + n.a_1 + n^2.a_2$$

substituting the expression for $A_w$ in equation (4.1.1), the model was obtained as,

$$Y = A_0 + a_0 \sum_w Xw \; + a_1 \sum_w wXw \; + a_2 \sum_w w^2 Xw \text{ .------------------(4.1.5)}$$

Equation (4.1.5) was extended for two weather variables to study joint effects.

The model obtained was

$$Y = A_0 + a_0\sum_w X_{1w} + a_1\sum_w wX_{1w} + a_2\sum_w w^2X_{1w} + b_0\sum_w X_{2w} + b_1\sum_w wX_{2w} + b_2\sum_w w^2X_{2w} + c_0\sum_w X_{1w}X_{2w} + c_1\sum_w wX_{1w}X_{2w} + c_2\sum_w w^2X_{1w}X_{2w} \quad \text{(4.1.6)}$$

An additional variable to represent year was included to make allowance for time trend.

Hendricks and Scholl (1943), Stacy (1957) and Runge (1968) have used this model to study joint effects of temperature and rainfall on crop yields. Baier (1977) made significant contributions in this field using Empirical Statistical models.

In the Empirical Statistical model approach, one or several weather variables or a time trend are related with yield. Usually the independent variables such as rainfall, maximum temperature, minimum temperature , moisture, humidity etc. are related to yield. The weighting coefficients are obtained by using the multivariate regression analysis. Validity of such empirical models depends on the design of the model as well as on the representativeness of the input data. Such valid models are used for predicting purposes as well.

Several empirical statistical models were developed all over the world. William et al (1975) (Canada) developed models using weather variables and trend. In USSR, multi-variable regression equations were developed using simple or quadratic expressions of agro-mateorological variables and biometrical characters. In Turkey, aridity index, and fertilizer consumption was used in the forecast model for wheat (Coffing, 1973). Thompson (USA, 1969, 1970) used monthly weather data (expressed as departure from normal) along with time trend (to represent technology) through multiple regression technique to obtain effects of weather and technology on crop yields. His equations were modified at the Centre for Climatic and Environmental Assessment, Columbia, Missouri by including an aridity index. An extensive review of the development and application of multiple regression models for USA is given in CIAP monograph 5 of the series 'Impact of climatic change on the biosphere' prepared by USA Department of Transportation, Climatic Impact Assessment Programme (Grobecker 1975).

The Joint Agricultural Weather Facility (JAWF), a world agricultural weather information centre was established in 1978 by US Department of Agriculture (USDA). JAWF employs crop-weather analysis models using weather data and derived agro-meteorological variables to estimate crop yield. Statistical regression models are used to evaluate weighting coefficients, which evaluates the effects of weather on crop yield. Frere and Popove (1979) used the method designed by Crop Ecology and

Genetic Resources unit of FAO in which actual rainfall data and climatological informations are used.

In India, various organisations like the Indian Meteorological Department are engaged in such studies involving weather factors and yield. Forecast models are obtained by employing multiple regression techniques. Sindhu et al studied the effect of weather on productivity using weather index based on rainfall, temperature, humidity and wind speed. They have used discriminant function to construct weather index.

Huda et al. (1975) ICRISAT developed regression type models using rainfall, mean temperature, solar radiation etc. Agrawal *et al.* (1980, 1983, 1986) and Jain *et al.* (1980) have developed forecast models for crops based on weather parameters. They modified the model suggested by Hendricks and Scholl expressing effects of changes in weather variables on yield in the wth -week as second degree polynomial in respective correlation coefficients between yield and weather variables. This will explain the relationship in a better way as it gives appropriate weightage to different periods. Thus the model for studying individual effects becomes

$$Y = a_0 + b_0 \sum_{w=1}^{n} X_{iw} + b_1 \sum_{w=1}^{n} r_{iw} X_{iw} + b_2 \sum_{w=1}^{n} r_i{}^2{}_w X_{iw} + cT$$

$$= a_0 + b_0 Z_0 + b_1 Z_1 + b_2 Z_2 + cT \text{ ----------------------------------(4.1.7)}$$

where Z's are generated variables st. $Z_j = \sum_{w=1}^{n} r_w{}^j Xw_1,\ j = 0,1,2$

Y is the yield, a, $b_j$ (j=0,1,2) and c are constants, T is the year number included to correct the long term trend in yield, n is the number of weeks upto the time of harvest, $X_w$ is the value of the weather variable in wth week, $r_w$ is the correlation coefficient between yield and the weather variable in $w^{th}$ week.

The effects on yield per unit change in weather variables in $w^{th}$ week can be calculated by differentiating the equation with respect to $X_w$. To study the joint effects of weather variables on yield, the above model has been extended by including interaction terms.

$$Y = a + b_{ij}Z_{ij} + \sum b_{i'j} Z_{i'j} + \sum b_{ii'j} Z_{ii'j} + cT \text{ ---------------------(4.1.8)}$$

where $z_{ij} = \sum_{w=1}^{n} r^{j}_{iw} X_{iw}$ and $Z_{ii'j} = \sum r_{ii'w} X_{iw} X_{i'w}$

$r_{iw}$ is the correlation coefficient of Y with the ith weather variable in the $w_{th}$ -week, $r_{ii}'w$ is the correlation coefficient of Y with the product of $i^{th}$ and $i'^{th}$ weather variables in the wth week. Rest of the variables have similar meaning as in the model for single effects.

Further modification of the model expressed the effects of changes in weather variables on yield in the $w_{th}$ week as a linear function of the respective correlation coefficients between yield and weather variables. The trend effect on yield was found to be significant( $r_w$ is obtained using adjusted yield)

Thus the model for studying the individual model becomes

$$Y = a + b_0 z_0 + b_1 z_1 + cT$$

## 4.2 Application in the present study

The annual marine fish catch in Kerala and the weather variables *viz.* rainfall (mm) and maximum temperature (°C) on the Kerala coast are studied with a view of understanding the effects of weather variables, if any, on the fish catch and to identify suitable statistical models incorporating these weather variables. The assumption made in this approach is that the effect of such variables on the annual fish catch depends to a large extent on its distribution over different months of the year. For example, effect of rainfall, if any, may not depend on the annual rainfall , but the distribution of rainfall over the entire year.

Multiple regression model with annual fish catch as dependent variable and weather variables as independent variables, single variable in distinct periods as independent variables, Hendrick and Scholl model in second degree polynomial in month number etc. are tried. Weather variables in quadratic terms also did not yield good result. However, taking the two variables rainfall and maximum temperature, the modified Hendricks and Scholl model, presented by Agarwal et al., using correlations based on yield adjusted for trend effect is found to be suitable for modelling the marine fish catch data.

The average monthly rainfall (mm) and temperature (°C) in Kerala, collected by the Indian Mateorological Department (Source : Weekly weather reports, IMD, and Facts and figures, Govt. of Kerala, 1980; 1990), and the annual marine landings published by the Central Marine Fisheries Research Institute formed the data base for this study.

The rainfall and maximum temperature for the period 1976-96 and the marine catch of Kerala (Source : CMFRI, Cochin) were utilized for model formulation, and based on the model and the weather data for 1996, fish catch for that year was predicted. Regression of fish catch ('000 T) on time (t = 1 to 20 for the years 1976 to 1995 respectively) is given by the linear model,

$$Y = 252.171358 + 17.070028\ t \qquad (4.2.1)$$

Value of $R^2$ =0.6273 and the coefficients are highly significant.

Using this model, the predicted catch, catch adjusted for trend for different years is calculated.

For studying the interactions, product of rainfall and maximum temperature ($X_1mX_2m$) for various months were tabulated.

Correlation matrix of adjusted catch with rainfall ($r_1m$) and maximum temperature ($r_2m$) and their product ($r_{12}m$) are presented in Table 4.1.

**Table 4.1: Correlation matrix of adjusted catch with the rainfall ($r_{1m}$), maximum temperature ($r_{2m}$), and their product ($r_{12m}$)**

| Variables | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RF $r_{1m}$ | -.1370 | -.1851 | -.0389 | -.0579 | .2891 | -.0685 | .4978 | -.0915 | -.1085 | .1864 | .1668 | -.4956 |
| MAXT $r_{2m}$ | -.4169 | -.3690 | -.4498 | -.2734 | -.4691 | -.5060 | -.4356 | -.3621 | -.4980 | -.4462 | -.5095 | -.3574 |
| $r_{12m}$ | -.1451 | -.1903 | -.0487 | -.0681 | .2660 | -.1478 | .5029 | -.1560 | -.1229 | .1591 | .1274 | -.5059 |

RF = rainfall (mm)

MaxT = maximum temperature ($^{0}$C)

The generated variables $Z_{10}$, $Z_{11}$, $Z_{20}$, $Z_{21}$, $Z_{120}$ and $Z_{121}$ are calculated and presented below in Table 4.2

**Table 4.2 : Generated Variables**

| Yr. No. | Catch'000 | $Z_{10}$ | $Z_{11}$ | $Z_{20}$ | $Z_{21}$ | $Z_{120}$ | $Z_{121}$ |
|---|---|---|---|---|---|---|---|
| 1 | 331.05 | 2072.30 | 349.52 | 371.67 | - 157.51 | 62408.2 | 8499.428 |
| 2 | 345.04 | 3226.20 | 545.65 | 371.76 | 157.25 | 97227.6 | 13144.560 |
| 3 | 373.34 | 3406.1 | 446.43 | 369.83 | - 156.44 | 101325 | 9458.221 |
| 4 | 330.51 | 2881.53 | 351.63 | 373.47 | - 158.00 | 86262.3 | 7103.456 |
| 5 | 279.54 | 2931.00 | 326.75 | 375.88 | - 159.20 | 88269.2 | 6244.204 |
| 6 | 274.4 | 3088.30 | 172.03 | 392.88 | - 166.31 | 97964.5 | 1404.294 |
| 7 | 325.37 | 2215.30 | 221.45 | 397.97 | - 168.73 | 71751.0 | 4344.561 |
| 8 | 385.27 | 2375.70 | 169.32 | 399.09 | - 169.21 | 76867.3 | 3243.617 |
| 9 | 393.47 | 2381.60 | 179.72 | 395.93 | - 167.76 | 76867.7 | 2847.850 |
| 10 | 325.54 | 2491.30 | 202.93 | 398.75 | - 168.90 | 80396.5 | 3347.948 |
| 11 | 382.79 | 2033.53 | 113.70 | 401.77 | - 170.22 | 66689.4 | 891.281 |
| 12 | 303.29 | 2246.03 | 61.20 | 404.41 | - 171.75 | 74766.5 | -1339.706 |
| 13 | 468.81 | 2557.50 | 190.51 | 403.16 | - 170.73 | 83325.4 | 3279.147 |
| 14 | 647.53 | 2642.00 | 279.14 | 390.92 | - 165.54 | 83436.3 | 5692.291 |
| 15 | 662.89 | 2780.00 | 463.92 | 379.60 | - 160.56 | 85288.5 | 11261.126 |
| 16 | 564.16 | 3106.00 | 387.75 | 382.7 | - 161.97 | 93877.9 | 7770.0763 |
| 17 | 560.74 | 3353.00 | 441.01 | 375.65 | - 158.87 | 101224 | 9429.7582 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 18 | 574.74 | 2818.60 | 443.59 | 373.0 | -157.96 | 84744.0 | 10059.920 |
| 19 | 568.03 | 3497.86 | 459.27 | 378.65 | -160.50 | 106223 | 10025.754 |
| 20 | 531.65 | 2920.70 | 457.41 | 375.34 | -158.92 | 89218.4 | 11335.278 |
| 21 | 572.06 | 2689.00 | 271.45 | 377.05 | -159.66 | 80559.7 | 5217.539 |

For the purpose of forecasting, we consider the data for the period 1976-1995 (20 years) for the analysis. With the models so formulated, the value of the variables for the next year can be predicted.

Using stepwise regression of catch on generated variables of rainfall and time, the model is found to explain 75 percentage of the variation ($R^2 = .75230$)with time and $Z_{11}$ as independent variables. The coefficients are tested to be highly significant ($p \leq .01$)

For the ANOVA, $F = 25.81619$, Sig $F = 0.0000$, $R^2 = 0.75230$

The model is

$$Y = 163.61209 + 15.83569 * t + 0.32419 * Z_{11} \qquad (4.2.2)$$

The single effect of rainfall on catch is given by the partial differential relation,

$$\partial Y / \partial X_1 m = 0.3242 * r_{1m} \qquad (4.2.3)$$

and the effects of rainfall on various months can be obtained by substituting the corresponding $r_{1m}$ values in the above relation.

In the other set of analysis for maximum temperature, the single effect of maximum temperature on catch, the regression model becomes,

$Y = 1395.149478 + 17.56304*t + 7.03008*Z_{21}$ --------------(4.2.4)

Estimates of the coeficients are highly significant ($p \leq 0.01$) and for the ANOVA, F= 21.31029 which is significant at 0.0000; $R^2 = .71486$.

Change in yield for one unit increase in maximum temperature in the $m^{th}$ month is given by

$\partial Y / \partial X_2 m = 7.030083 * r_{2m}$ ----------------------------------------(4.2.5)

Now, considering the combined effect of the weather variables rainfall and maximum temperature on catch, we take the generated variables $Z_{120}$ and $Z_{121}$ , for the period 1976-1995. Application of the stepwise regression of yield on these generated variables and time gives the model,

$Y = 188.62832 + 15.80489\ t + 0.0120\ Z_{121}$ -----------------(4.2.6)

The results of regression analysis is furnished as below.

| Variable | B | SE B | Beta | t-value | Sig t |
|---|---|---|---|---|---|
| Year | 15.804890 | 2.55452 | .73332 | 6.187 | .0000 |
| $Z_{121}$ | .01200 | .00376 | .37826 | 3.191 | .0053 |
| (Constant) | 188.62832 | 36.19815 | | 5.211 | .0001 |

Table :4.3 ANOVA

| | DF | Sum of squares | Mean Squares |
|---|---|---|---|
| Regression | 2 | 236905.09980 | 118452.54990 |
| Residual | 17 | 71995.01256 | 4235.00074 |

F=27.96990, Sig F = .0000, $R^2=0.76693$

The joint effects of these weather variables can be obtained by partially differentiating the above equation with respect to $X_{1m}$ and $X_{2m}$.

$\partial Y / \partial X_1 m = 0.0120 * X_{2m} \; \gamma_{12m}$ ------------------------------------(4.2.7)

$\partial Y / \partial X_2 m = 0.0120 * X_{1m} \; \gamma_{12m}$ ------------------------------------(4.2.8)

Now using the above model (4.2.6) we can forecast the fish catch for the $21^{st}$ year by substituting the value of $Z_{121}$ for that year.

Thus the forecast is

$Y_F = 188.62832 + 15.80489 * t + 0.0120 * 5217.53902$ ---(4.2.9)

= 583.1415 which is very close to the actual value, given by $Y_A$ = 572.06. Thus the prediction model is a very good fit, as observed from the analysis of variance, $R^2$ value and the forecast. Infact, by including the variable $Z_{121}$, the variability explained by the model has been enhanced by 14 percent from 62.7 to 76.7 percent. This shows that the joint effect of rainfall and temperature on marine fissh catch on the Kerala coast is substantial.

## 4.3 Multiple regression model using environmental parameters.

We have formulated forecasting models in the last sections involving two different approaches for prediction of fish catch using environmental parameters, rainfall and maximum temperature as explanatory variables. Another model using a multivariate approach is presented where a number of independent variables (maximum temperature, rainfall, humidity (am), humidity (pm), effort and time) are incorporated. Draper, N.R. and Smith, H. (1996) have described the applied regression approach in detail. Montgomery, D.C. and Peek, E.A, (1982) and Derek J.Pike (1981) have given methodologies for linear regression analysis. In the present study the model to be formulated is a multiple regression model using fish catch as the dependent variable and environmental parameters, effort (boat days) and time (Years) as independent variables.

***The model approach***

The multiple regression model can be expressed in the form

$$Y_i = \beta_0 + \beta_{1i} X_{1i} + \beta_{2i} X_{2i} + \dots\dots\dots\dots + \beta_{ki} X_{ki} + e_i$$

where Y is the dependent variable and $X_1$, $X_2$, .......$X_k$ are the k regressors, β's are the unknown parameters, called the regression coefficients, to be estimated for inputting into the model and the $e_i$ terms are independent random variables that are normally distributed with mean 0 and constant variance $\sigma^2$.

Thus $e \sim N(0,\sigma^2)$.

More complex models including quadratic terms and cross product terms are possible to fit models using computer packages. But such indiscriminate use of data without understanding the underlying structure of the data will not reflect the pattern of variation present in the data. Study of data set prior to analysis and use of simple graphical techniques will be of great help to identify suitable models for formulation using computers.

***Analysis of variance*** :

Analysis of variance in multiple regression provides a method of partitioning the over all variation between the observations into variation which has been explained by the regression equation and residual or unexplained variation. The F-test associated with the analysis of variance is the same as testing the null hypothesis $H_0 = \beta_i = 0$ where $\beta_i$'s are partial regression coefficients. In other words, it is a test of whether there is a linear relationship between the dependent variable and the entire set of independent variables.

***Preparation of data for analysis*** :

Before proceeding to regression analysis the data should be subjected to proper editing. Removal of outliers and multicollinearity are two major steps involved in this direction.

***Detection of Outliers***

A plot may indicate presence of points suspiciously different from others. They are known as outliers and act as high leverage points.

Outliers give responses inconsistent with the remaining data points. They greatly influence the least square estimates and can be identified by plotting the residuals and stimulus variable. Such points may be removed from the data for fitting the regression models. Some of the commonly used influential observations diagnostics are residuals $\gamma_i = Y_i - \hat{Y}_i$ , pairwise plots $X_i$ vs $X_j$ and Y Vs. $X_i$, residual and partial residual plots, the 'Hat' matrix and its diagonal elements hii, 'Studentized' residuals ti and ti*, (ti = $\gamma_i / \sqrt{(1-hii)S_i^2}$ and ti* $= \gamma_i / S_i \sqrt{1-hii}$) where $S_i^2$ is the residual mean square for the regression in which the ith case has been deleted), Cooks distance measure,Di) DFFIISi & DFBETASi, COVRATIOi, WSSDi (Hocking and Pendleton, 1983) and Mahalanobi's distance Di.

Cook, R.D. (1977, 1979) made an indepth study for the detection of influencial observations in the regression analysis. Belsley, D.A, Kuh, E. and Welsch, R.E. (1980) and, Velleman, P.F. and Welsch, R.E. (1981) also made detailed examination of the computation of regression diagnostics.

***Multicollinearity***:

In multiple regression, the independent variables are expected to be uncorrelated or weakly inter-related. Otherwise, the result may be anomalous. The presence of highly correlated independent variables in regression is known as multicollinearity.

Multicollinearity inflates the variances of the estimates, making individual coefficients quite unreliable. Silvey, S.D. (1969) studied the lack of precision of estimates owing to multicollinearity. The overall regression may be significant while none of the individual coefficients prove to be significant. Hocking and Pendleton (1983) have given various statistics like simple pairwise correlations, the squared multiple correlation coefficient, $R_i^2$, the variance inflation factors (VIFs), eigen values etc. for detection of multicollinearity. $(VIF)_k = 1/(1-R_k^2)$ where $R_k^2$ is the square of the multiple correlation coefficient of the $K^{th}$ independent variable on the rest of them. $(VIF)_k = 1$ when $R_k^2 = 0$ and $(VIF)_k = \infty$ when $R_k^2 = 1$. Eigen values nearing zero, $R_i^2 > 0.9$ or VIF > 10 are useful indicators of multicollinearity. To lessen the impact of multicollinearity, use of some respecification of the regressors such as using a function of type $X = (X_1 + X_2)/X_3$ for the nearly dependent Xis or variable elimination approach are employed. An alternative method to overcome the problem of multicollinearity, known as Ridge Regression is described by Hoerl & Kennard (1970).

***Variable selection*** :

When a number of explanatory varibles are measured, the problem arises as to which of these variables are to be included in the model. Thompson, L.M. (1978) detailed the selection of variables in multiple regression. In many cases, measuring a number of variables may be cumbersome and costly. Often, the researcher may be confronted with conflicting objectives. The inclusion of more variables may give rise to the increase in the information content in these variables for prediction of the dependent variable. On the other hand, variance of estimate of the dependent variable may increase with the increase of the explanatory variables. In fact, the researcher would like to formulate a model which is more compact rather than complex, so that both the costs and efforts are controlled. In this situation, he has to select variables, by restricting only important variables for effective prediction. The identification of proper subset of regressors for the model assumes great significance and is called the variable selection problem. Abt,K. (1967) studied the methodology for identification of the significant independent variables in linear models. Mallows, C.L. (1966) and Thompson, M.L.(1978) and Allen D.M. (1971) studied the variable selection problem in detail.

Some approximate methods are available for choosing the appropriate subset variables. However, one should use his experience and knowledge to visualise and assess the stimulus variables and their association with the explanatory variables. The following three criteria are closely related to each other

*Regression on all subsets*

It consists of performing regression on all possible subsets of independent variables and select the best subset using either the multiple correlation coefficient $R^2$ or the residual mean square or Mallows Cp statistic.

(I) $R^2$ , the coefficient of determination, represents the proportion of the total sum of squares explained by the regression. Larger $R^2$ value implies better fit of the straight line to the data. For K variables, we can have $2^k$-1 subsets of independent variables where

$R_p^2 = 1 - \frac{SSE_p}{SST}$, for each p variable subsets of K, SSEp being the error sum of squares and SST, the total sum of squares. Also, for each p, there are $\binom{K}{p}$ values of $R_p^2$. $R_p^2$ increases as p increases and is maximum when p = K. We can either compare the maximum $R_p^2$ for each p or plot maximum $R_p^2$ against p and determine the number of variables to be included.

The sample $R^2$ is an estimate of the extent to which the model fits the population. The statistic adjusted $R^2$ attempts to correct $R^2$ to closely reflect the goodness of fit of the model in the population and is given by $R_a^2 = R^2 - [p(1-R^2)/N-p-1]$ where p is the number of independent variables and N is the total number of observations. The subset chosen is the maximum $R_a^2(p)$

Aikake's information criterion $AIC = NL_n(SSE/N) + 2p$ and Schwarz Bayesian criterion $SBC = N\ Ln(SSE/N) + pLn(N)$ are dissscussed by Judge *et. al.* (1985).

(ii) As the true model minimises the residual mean square, we select the subset of independent variables with minimum MSEp for p variables. We can also plot MSEp versus p and find that MSEp initially decreases, then stabilises and again increases. The increase in MSEp occurs due to the reductions in the degrees of freedom in SSEp as the regression degrees of freedom increases. However minimum MSEp = Maximum $R_a^2(p)$.

iii) Mallows (1966) proposed a criterion, Cp which is defined as $Cp = SSEp/S^2 + 2p-n$

where SSEp : Error sum of squares with p variables in the model.

$S^2$ : Residual mean square from the full model

n : number of observations (sample size)

This method uses the full model with all terms as base of reference. It also provides a graphical means of presenting the results and choosing an appropriate model.

For negligible bias, Cp approximates to p. Cp is plotted against p and choose the model with Cp near to p, but preferably less than p. A draw back is that we have to evaluate Cp for all $2^k$-1 subsets of the independent variables. Graphical methods of evaluation of models based on Cp are discussed in Daniel and Wood (1980) and Draper & Smith (1981).

***Sequential Procedures***

We can construct $2^k$-1 regression models from k independent variables. Evaluating all such regressions require a great deal of computations. So methods of evaluating only a small subset of regressions by adding or deleting regressors one at a time have been developed which are known as stepwise or sequential procedures. More frequently used among them are forward selection, backward elimination and stepwise regression.

***Multiple regression models of total fish catch on environmental parameters.***

As stated in the introductory part of this section, attempt was made to formulate multiple regression models with total fish catch as dependent variable, and environmental factors, fishing effort and time as explanatory variables using a general modelling approach and using the sequential procedures, as explained in the previous section.

Total fish catch from mechanised trawlers from Cochin fisheries harbour for 72 months during the period 1990-95 along with the corresponding data on fishing effort (Source: CMFRI), maximum temperature, minimum temperature, rainfall (mm), humidity (am), humidity (pm) and time (serial number of the month)

(Source : Weekly weather report, IMD) were subjected to regression analysis. The results are furnished below.

***Regression analysis of trawler catch at CFH***

The regression analysis indicate the value of $R^2$ as 0.7683 with an F value = 30.30982 (significant at .0000) which gives an indication of a good model.

However, a further probe into the analysis show that the coefficients of all the independent variables are not significant. Time, minimum temperature, humidity (am) are significant only at 28.2, 60.5, and 72.8 percentages respectively. Consequently, the significance of the constant term in the model is 18.6 percent.

The B values in the analysis are the weights attached to each independent variable. But they are not indicators of the relative importance of the variables. The magnitude of the coefficients depends on the units in which they are measured. Here the units of measurement are totally different and hence the coefficients are non-comparable with regard to their relative importance.

The comparison of the coefficients to a great extent can be done by calculating the beta weights which are coefficients of the variables when they are expressed in standardized form (Z-score). They can be calculated using the relation,

BETAk = $B_K(Sk/Sy)$ where Sk is the standard deviation of the kth independent variable. However, the Beta coefficients, like the

Bvalues, are affected by the correlations of the independent variables.

The Beta values in the table are very low for the variables *viz.* serial number (time), minimum temperature and humidity (am), indicating low priorities for these variables in the regression model and hence they can be safely excluded.

The correlation matrix of the variables clearly indicate multicollinearity as the independent variables Humidity (am), Humidity (pm), rainfall (mm) are significantly correlated. Also, the dependent variable fish catch is highly correlated with effort, humidity (pm) and maximum temperature.

Thus taking into consideration of the correlation matrix, significance of B coefficients and Beta values, the most important variables for the model turn out to be effort, humidity and maximum temperature. By including humidity (pm) in the model, the effect of multicollinearity is reduced and information content, if any, of the humidity (am) and rainfall (mm) is protected.

The regression analysis with fishing effort (in boat days), humidity(pm) and maximum temperature as independent variables gives $R^2$ value equal to 0.72 ANOVA give F value=58.41847, significant at .0000 level, Beta values are reasonably high and coefficients of the variables are highly significant. Coefficient of the constant term is significant only at

12.3%. Changing the variable Humidity (pm) to humidity (am), the regression gives $R^2$ = 0.70 and the constant term is significant at 22.3%. Thus the first model is more acceptable.

The model is

$$Y = 11729.9943 + 0.5761\ X1 + 94.1983\ X2 - 636.7218\ X3 \qquad \text{.................................(4.3.1)}$$

where Y is the total fish catch by trawlers, X1, X2, and X3 are independent variables fishing effort, humidity (pm), and maximum temperature respectively. As indicated by the coefficients, rise in maximum temperature results in less catch where as increase in humidity (pm) is favourable to increased fish catch.

Now, deleting the variable maximum temperature, B values are as under.

| Variable | B value | Sig T |
|---|---|---|
| Effort | .52544 | .0000 |
| Humidity (pm) | 160.82711 | .0000 |
| (Constant) | -12503.3338 | .0000 |

Here all coefficients are highly significant, F Value = 71.8371, significant at .0000, but $R^2$ Value reduces to 67.556 compared to the above model

*Application of Sequential Procedures*

Stepwise regression is considered to be more versatile than forward selection or backward ranking. This procedure is applied to select the best subset of independent variables viz. effort (boat days), rainfall (mm), maximum temperature, humidity (am) and humidity (pm) at Cochin to construct a regression model with dependent variable, the trawl catch at the Cochin fisheries harbour. Models are formulated with the same data base used for the previous models.

Application of the stepwise procedure using SPSS/PC+ gives that the $R^2$ value increases from 0.415 at the 1st step to 0.764 at the fifth step. Variables *viz.* effort and maximum temperature (step 2) gives $R^2 = 0.676$ and inclusion of minimum temperature in the model gives $R^2 = 0.721$. The coefficients of these variables are highly significant.

As more variables are included in order of importance, the residual mean square will generally reduce and then increase. For each variable included in the model, the significance of reduction in residual mean square can be tested by F-test.

$$\text{Calculate } F_{1,f_2} = \frac{RSS_1 - RSS_2}{RSS_2 / f_2}$$

where $RSS_1$, $RSS_2$ are the residual sum of squares at the first and second steps (when a new variable is included) respectively, and f1&f2 are the corresponding degrees of freedom. $(f_1 - f_2) = 1$. If F is significant, we conclude that the reduction in residual mean square is significant {Dereck J. Pike (1986)}. Here, F value is reduced upto step 4 and it rises at step 5 with the inclusion of the last variable.

The models at the 3rd and 4th steps with the respective $R^2$ values are

$$Y = 25408.921 + 0.563\ X_1 - 1287.621\ X_2 + 563.354\ X_3 \quad \ldots\ldots\ldots(4.3.2)$$

Where $X_1$ , $X_2$ & $X_3$ are independent variables viz. effort, maximum temperature and minimum temperature respectively and Y is the dependent variable, the total fish catch $R^2$ value is 0.72.

By including rainfall (mm) at step 4, $R^2$ value is slightly improved from 0.72 to 0.74. But as the rainfall (mm)and temperature are significantly correlated, we can exclude this variable on subjective judgement. Inclusion of the last step (step 5) gives $R^2 = 0.76$, but some of the regression coefficients show non-significance and hence not acceptable.

Thus the model (4.3.2) is accepted as a good fit to the data.

Forward selection procedure has given exactly the same figures as in the stepwise and hence the results are not presented separately.

Now, using the Backward elimination procedure, it is noted that two variables humidity (am), and minimum temperature are removed from the set of independent variables. $R^2$ value remains at 0.76 even after these removals. The result shows that the model is similar to model (4.3.2) . Thus different procedures applied above yield almost equally efficient models.

***Fish catch Vs Environmental parameters - Kerala***

<u>Model-2</u>

Several empirical statistical models were developed all over the world with yield as response variable and one or more environmental factors like temperature, rainfall, moisture etc. as independent variables. In such empirical models, the coefficients are derived empirically using standard statistical procedures such as the multiple regression analysis. The models are generally used for the purpose of forecasting. Thompson (1969, 1970) used monthly weather data expressed as departures from normal, along with time trend to obtain effects of weather and technology on crop yields.

Of the many empirical-statistical models tried in connection with this study, the model suggested by Thompson was found to be appropriate for fish landings in Kerala. Instead of monthly weather data, annual rainfall data was converted into departure from normal rainfall for the study. Using the annual fish catch and the annual rainfall for the past 40 years, an attempt to formulate a model was made. Multiple regression model with annual fish catch as response variable, time and annual rainfall (as departure from normal) as independent variables, was tried. The results obtained are indicated as under :

| | | |
|---|---|---|
| Multiple R | : | 0.78154 |
| R Square | : | 0.61081 |
| Adj. R Square | : | 0.59032 |
| Standard Error | : | 79.18494 |

**Table 4.4 : Analysis of variance**

| | DF | Sum of squares | Mean square |
|---|---|---|---|
| Regression | 2 | 373947.06410 | 186973.532015 |
| Residual | 38 | 238269.65687 | 6270.2541 |

F= 29.81913 Sig F= .0000

**Table : 4.5 :Variables in the equation**

| Variable | B | SE B | Beta | t | Sig t |
|---|---|---|---|---|---|
| RF-Normal | .050107 | .025686 | .202574 | 1.951 | .0585 |
| Time | 8.278625 | 1.072462 | .801607 | 7.719 | .0000 |
| Constant | 219.553639 | 25.246464 | | 8.696 | .0000 |

$R^2$ value is .61081 and thus the model explains 61.08 percent of the variations. The ANOVA shows a very highly significant F-value for the regression. The coefficients of the independent variables and also the constant are highly significant as seen from their respective values. Thus model is a very good fit, given by $Y = 219.5336 + 8.2786*T + 0.0501*R$ ---------------(4.3.3)

where Y stands for the annual catch in tonnes, T represents the time and R represents the deviation of annual rainfall (mm) from the normal rainfall.

Using this model, the fishery forecast for the next year can be predicted,. The forecast is observed to be very close to the actual estimates.

## Reference


Abt, K. (1967). On the identification of the significant independent variables in linear models. *Metrika*, **12**, 2-15.

Agarwal, Ranjana, Jain, R.C., Jha, M.P. and Singh, D. (1980). Forecasting of rice yield using climatic variables. *Ind. J. Agric. Sci.* **50**(9), 680-684.

Agarwal, Ranjana, Jain, R.C. and Jha, M.P. (1983). Joint effects of Weather variables on rice yield, *Mausam*, **34**(2), 189-194.

Agarwal, Ranjana, Jain, R.C. and Jha, M.P. (1986). Models for studying rice crop-weather relationship, *Mausam* , **37**(1), 67-70.

Agarwal, Ranjana and Jain, R.C. (1989). Studies to develop models for obtaining pre-harvest forecast of wheat yield on the basis of weather parameters. IASRI Publication.

Allen, D.M. (1971). Mean Square error of prediction as a criterion for selection variables. *Technometrics*, **13**, 469-475.

Anon. (1981). Facts and Figures, Govt. of Kerala.

Anon. (1991). *Facts and Figures*, Govt. of Kerala.

Baier, W. (1977). Crop weather models and their use in yield assessments. Tech. Note. No. 151, WMO, Geneva, pp.48.

Belsley, D.A., Kuh, E. and Welsch, R.E. (1980). *Regression Diagnostics*, John Wiley and Sons, New York.

Coeffing, A. (1973). Forecasting wheat production in Turkey. Foreign Agricultural Economic report No.85, US Department of Agriculture, Economic Research Services, pp. 38.

Cook, R.D. (1977). Detection of influential observations. Technometrics, 19, 15-18.

Cook, R.D. (1979). Influential observations in linear regression. *J. Am. Stat.Asso.*, **74**, 169-174.

Daniel, C. and Wood, F. (1980). Fitting equations to Data. Rev. ed. John Wiley and Sons, New York.

Derck J. Pike. (1986). A practical approach to regression: In the book Statistical procedures in Food research. Edited by J.R. Piggott, published by Elsevier Applied Science, London.

Draper and Smith. (1981). Facts and Figures, Govt. of Kerala.

Fisher, R.A. (1924). The influence of rainfall on the yield of wheat at Rothamsted. Roy. Soc. (London), Phil. Trans. Serv. B., 213, 89-142, Illus.

Frere, M and Popov, G.F. (1979). Agrometerological crop monitoring and forecasting. FAO plant productions and Protection Paper, FAO, Rome.

Handrick, W.A. and Scholl, J.C. (1943). Technique in measuring joint relationship. The joint effects of temperature and precipitation on drop yield. N. Carolina Agric. Exp. Sta. Tech. Bull. 74.

Hoerl, A.E, and Kennard, R.W. (1970). Ridge regression: Biased estimation of non-orthogonal problems. Technometrics, 12, 55-67.

Jain, R.C., Agarwal, Ranjana, and Jha, M.P. (1980). Effects of climatic variables on rice yield and its forecast. Mausam , 31(4), 591-596.

Judge, G.G., Griffiths, W.E. Hill, R.C. Lutkepohl, h. and Lee, T.D. (1985). The Theory and Practical of Econometrics, 2nd ed. John Wiley and Sons, New York.

Kalawar, A.G., Devaraj, M and Parulekar, A. H. (1985). Report of the expert committee on Marine Fisheries in Kerala. Submitted to Govt. of Kerala. PP. 467.

Laevastu, T and Hayes, M.L. (1981). Fisheries Oceanography and Ecology, Fishing News Book Ltd., England, pp.199.

Mallows, C.L. (1966). Choosing a subset regression presented at Joint Statistical Meetings, Los Angeles, California.

Montgomery, D.C. and Peek, E.A. (1982). Introduction to Linear Regression Analysis. John Wiley and Sons, New York.

Runge, E.C.A. (1968). Effects of rainfall and temperature interactions during growing season on crop yield. Agron. J. 60, 503-507.

Silvey, S.D. (1969). Mutlicollinearity and imprecise estimation. J.R. Statist. Soc. Ser. B, 31, 539-552.

Stacy, S.V., Stemson, D. Jones, L.S. and Foreman, J. (1957). Joint effects of maximum temperatures and rainfall on crop yield.

Thompson, L.M. (1963). Evaluation of weather factors in the prediction of wheat in the United States. J. of Soil and Water Conservation, 17, 149-156.

Thompson, L.M. (1969). Weather and Technology in the production of wheat in the United States. J. of Soil and Water conservation, 17, 149-156.

Thompson, L.M. (1970). Weather and Technology in the production of Soybeans in the Central United States. J. Agronomy, 62, 232-236.

Thompson, L.M. (1978). Selection of variables in multiple regression. Part I. A review and evaluation. Int. Statistical Review, 46, 1-96.

Velleman, P.F. and Welsch, R.E. (1981). Efficient computing of regression diagnostics. The American Statistician, 35, 234-242.

William, D.V., Jooynt, M.L. and Mc Comicm, P.A. (1975). Regression analysis of Canadian prairie crop yield, 1961-72, in relation to Weather, Soil and Trend. Canadian J. of Soil Sci. 55, 43-53.

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# CHAPTER 5

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# APPLICATION OF BOX-JENKINS MODELS IN FISHERY EXPORT

## 5.0 Introduction

Marine products export from India occupies a prime position among premier exporting items in the country. The fish processing industry has acquired large infrastructural facilities over the years and also owing to diversification of fishery products, India's marine products export has grown upto 2,96,277 tonnes in quantity and 3501 crores of rupees in foreign exchange during the year 1995-96. The frozen shrimp is a major item of export with a quantity of 95,697 tonnes earning 2356 crores during the same year. Our country has 1190 marine product exporters, 367 freezing plants, 14 canning plants, 148 ice plants, 445 cold storages and about 900 fish pealing sheds. (Source : Marine Product Export Development Authority, Cochin). Apart from earning huge amount of foreign exchange the fish processing industry provides meaningful employment to large number of people.

Contribution of Kerala to the foreign exchange earnings from marine products is very substantial, amounting to over 900 crores rupees in 1996.The major export market continue to be Japan and USA, apart from the developing European markets. Marine exports from Kerala plays a crucial role in the state's economy. In this chapter an effort is made to study the trend of marine product exports from Kerala, using the time series data by the application of ARIMA models.

## 5.1 ARIMA MODELS

Forecasting plays a crucial role in business, Industry, government and institutional planning because many important decisions depend on the anticipated future values of certain variables. Forecasts can be made in many different ways, the choice of the method depending on the purpose and importance of the forecasts as well as the costs of alternative methods. In this chapter, the Box-Jenkins model also referred to as ARIMA (Auto regressive integrated moving average) models are applied to marine exports data. Univariate or single series means that forecasts are based only on past values of the variable being forecast, they are not based on any other data series.

We shall be concerned with forecasting time-series data. These data refer to observations on a variable that occur in a time sequence. We denote by $z_t$, the observation made at time t. Thus, a sequence of n observations ( a time-series involving n points) may be represented as $z_1, z_2, \ldots\ldots\ldots, z_n$ .

The Box-Jenkins models are specially suited to short term forecasting because most ARIMA models place greater emphasis on the recent past rather than the distant past.

Long term forecasts from ARIMA are less reliable than short term forecasts. The Box-Jenkins method applies to both discrete data as well as to continuous data. However, the data should be available at equally spaced discrete time intervals. Also, building of an ARIMA model requires a minimum sample size of about 35-40 observations.

The Box-Jenkins method applies only to stationary time series data. A stationary time series has a mean, variance and auto-correlation function that are essentially constant over time. An auto-correlation function is one way of measuring how the observations within a single data series are related to each other. The stationarity assumption simplifies the theory underlying the Box-Jenkins models and also helps to ensure that we get useful estimates of parameters from a moderate number of observations. If a time series is stationary then the mean of any major subset of the series does not differ signficantly from the mean of any other subset. Similarly, if a data series is stationary then the variance of any major subset of the series will differ from the variance of any other major subset only by chance.

Before attempting to choose an appropriate ARIMA model for forecasting, it is necessary to apply some transformation to the data so that we have a stationary time series. One of the simplest transformations is the process of differencing. To difference a data series, we define a new variable $w_t$ given by

$$W_t = z_t - z_{t-1}, t = 2,3,\dots\dots\dots, n.$$

The series $W_t$ is called the first differences of $z_t$ . Similarly, we can define the second differences of the series as

$$V_t = W_t - W_{t-1}$$

$$= (z_t - z_{t-1}) - (z_{t-1} - z_{t-2}); \; t = 3,4,\dots\dots\dots, n)$$

When the mean of the time series is stationary we may treat the mean as a deterministic component of the series. To focus on the stochastic behaviour of the series, we express the data as deviations from the mean. That is, we define a new time series $z^*_t$ , where

$z^*_t = Z_t - \bar{Z}$ ; $\bar{Z}$ being the mean of the stationary series.

Next, we make a graphical analysis of the data series. For this we plot $z^*_{t+k}$ (k = 1,2, .....) against the previous observations $z^*_t$. The pairs of values ($z^*_t$, $z^*_{t+1}$ ) are then plotted on a graph to see the kind of relationship between observations separated by one time period. Similarly one can see the relationship between the observations separated by two time periods and so forth. The upper limit on the value of k is determined by the number of observations in the series.

Though, this type of graphical analysis might give a rough idea about how the observations are related to each other, to get a better idea of the relationship, one uses the tools of the estimated autocorrelation function (acf) and estimated partial autocorrelation function (pacf). The idea of auto-correlation coefficient for each set of ordered pairs $(z^*_t, z^*_{t+1})$.

Box and Jenkins suggest that maximum number of useful auto-correlations is roughly n/4 where n is the number of observations.

Looking at the pattern in an estimated acf is a key element at the identification stage of the Box-Jenkins procedure. The significance of the estimated acf can be tested by an approximate t-test given by

$t = r_k/s(r_k)$ where $s(r_k)$ is the approximate estimated standard error of $r_k$, $r_k$ denotes the estimated autocorrelation coefficient of observations seperated by k time series.

The significance of the estimated pacf can be tested with the help of t-test.

One of the most common ARIMA processes has the algebraic from $z_t = c + \varphi_1 z_{t-1} + a_t$.

Such processes with past (time-lagged) z terms are called Auto-regressive (AR)processes. The longest time lag associated with a z term on the right hand side is called the order of the process. This equation defines an AR process of order one. It tells us how the observed values of $z_t$ are likely to behave through time. The coefficient $\varphi$ is a fixed parameter which tells how $z_t$ is related to $z_{t-1}$, c is a constant term related to the mean of the process. The variable $a_t$ indicates the random shock or disturbance term.

Another common ARIMA process has the algebraic form

$$z_t = c - \theta_1 a_{t-1} + a_t$$

Such a process is called a Moving Average (MA) process.

The third common ARIMA process has the algebraic form

$$z_t = \delta + \phi_1 z_{t-1} + \ldots\ldots\ldots \phi_p z_{t-p} - \theta_1 a_{t-1} \theta_2 a_{t-2} \ldots. \theta_q a_{t-q} + a_t$$

Where $\delta$ is a constant term related to the mean of the process. This is called a mixed autoregressive moving average model of order (p,q). It contains both AR and MA terms. Thus a mixed auto-regressive-moving average model of order (1,1) is

$$z_t = \delta + \phi_1 z_{t-1} + a_t - \phi_1 a_{t-1}$$

Requisites of a good model are that the model is parsimonious (uses the smallest number of coefficients needed to explain the available data), it is stationary, it is invertible, it has statistically independent residual and has small forecast errors. (Pankartz (1983))

## 5.2 Application of ARIMA models in marine export

Monthly export data for 96 months for the period ending 1995-96 (Source : Marine Products Export Development Authority, cochin) were used for this study. For identifying the appropriate ARIMA models the ACF and PACF were calculated which are given below.

**Table 5.1: Autocorrelations of marine exports from Kerala**

| lag | Aut corr. | PAC | Aut. corr. diff(1) | PAC diff(1) | Aut.corr. seasonal diff(1at12) | PAC seasonal diff(1at12) |
|---|---|---|---|---|---|---|
| 1. | .563 | .563 | -.248 | -.248 | .365 | .109 |
| 2. | .334 | .026 | -.011 | -.077 | .1 | .109 |
| 3. | .115 | -.121 | -.191 | -.228 | -.086 | .109 |
| 4. | .056 | .045 | -.059 | -.194 | -.056 | .109 |
| 5. | .053 | .054 | .038 | -.075 | -.034 | .109 |
| 6. | .022 | -.046 | -.045 | -.143 | -.115 | .109 |
| 7. | .03 | .028 | -.045 | -.188 | -.073 | .109 |
| 8. | .079 | .0296 | -.112 | -.280 | -.096 | .109 |
| 9. | .235 | .224 | .003 | -.278 | .125 | .109 |
| 10. | .390 | .234 | .142 | -.144 | .155 | .109 |
| 11. | .411 | .085 | .030 | -.199 | .084 | .109 |
| 12. | .410 | .152 | .242 | .105 | -.265 | .109 |
| 13. | .192 | -.154 | -.144 | -.034 | -.227 | .109 |
| 14. | .087 | -.026 | .008 | .011 | -.151 | .109 |
| 15. | -.019 | -.056 | -.097 | -.011 | -.099 | .109 |
| 16. | -.037 | -.021 | -.046 | -.067 | -.035 | .109 |
| 17. | -.014 | .027 | -.023 | .086 | -.029 | .109 |
| 18. | .037 | .057 | .013 | .00 | .063 | .109 |
| 19. | .074 | -.036 | -.071 | .107 | .073 | .109 |
| 20. | .161 | .043 | .171 | .173 | .164 | .109 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 21. | .111 | -.216 | -.069 | .018 | .012 | .109 |
| 22. | .116 | -.070 | .045 | -.04 | -.027 | .109 |
| 23. | .083 | -.008 | -.035 | -.066 | -.129 | .109 |
| 24. | .078 | .025 | .057 | -.089 | -.097 | .109 |
| 25. | .037 | .077 | .021 | -.002 | -.066 | .109 |
| 26. | -.027 | -.019 | .01 | .063 | -.122 | .109 |
| 27. | -.101 | -.093 | -.095 | -.004 | -.145 | .109 |
| 28. | -.096 | -.036 | -.061 | .004 | -.074 | .109 |
| 29. | -.034 | -.032 | .04 | .046 | -.009 | .109 |
| 30. | -.007 | -.077 | .000 | -.08 | -.037 | .109 |
| 31. | .008 | .045 | .010 | -.05 | -.088 | .109 |
| 32. | .023 | .044 | -.017 | -.185 | -.089 | .109 |
| 33. | .053 | .172 | .053 | .024 | -.009 | .109 |
| 34. | .031 | -.058 | -.014 | -.047 | .032 | .109 |
| 35. | .031 | .033 | -.042 | .00 | .109 | .109 |
| 36. | -.009 | -.060 | -.035 | -.079 | .029 | .109 |

From the autocorrelations for lags 1 to 36, given above no model identification was possible. For a pure stationary auto regressive model of order p, the theoretical autocorrelations will die down as the lag increases and the theoretical partial autocorrelation will cut off after lag p. Similarly, for a pure stationry moving average model of order q the theoretical autocorrelations will cut off after lag q and the theoretical partial autocorrelaiton will die down.

In the marine export data autocorrelation for difference 1 and seasonal difference (1 at 12), partial autocorrelations for difference 1, seasonal difference (1 at 12) also were worked out. With these results no model identification was possible, as it did not show any trend. For the other sets of data namely shrimp exports from Kerala, shrimp exports to US and shrimp exports to Japan, the corresponding autocorrelations were worked out seperately. For these sets also no specific model identification was possible. Hence, other probable suitable models were probed.

### 5.3 Marine Export from Kerala

The seasonal ARIMA model found suitable for the marine export data is ARIMA (1,0,0) (0,1,1). That is the order of autoregression is 1, order of differencing is zero, order of moving average terms is zero, order of seasonal atuoregression is zero, order of seasonal differencing is unity, order of seasonal moving average term is 1 and seasonality is 12. Compared to the general seasonal ARIMA model

$\phi(B)\ \Phi(B^s)\ \nabla^d\ \nabla_s^D\ y_t = \theta(B)\ \Theta(B^s)\ a_t$. The polynomials in terms of the back shift operator B, for this model are $\phi(B) = 1-\phi_1 B$; $\theta(B) = 1$,

$\nabla^d = \nabla^D = 1$

$\nabla_s^D = \nabla^1{}_{12} = 1-B^{12}$, $\Phi(B^s) = 1$

and $\Theta(B^s) = 1 - \Theta_1(B^{12})$

$\therefore$ The model in terms of the series $y_t$ and the innovations $a_t$ is

$(1-\phi_1 B).1.1.(1-B^{12})\, y_t = 1.(1-\theta_1 B^{12})\, a_t$

*ie* $(1-\phi_1 B)(1-B^{12})\, y_t = (1-\theta_1 B^{12})\, a_t$

*ie* $y_t = \phi_1(y_{t-1} - y_{t-13}) + y_{t-12} + a_t - \theta_1 a_{t-12}$ --------------------------(5.3.1)

Using the ARIMA estimation program available in the trends module of SPSS software parameters of the model were estimated. This software use Melard's algorithm for estimation of the model parameters. The accuracy of the constants for this iteration were fixed as .001, maximum value for the Marquardat constant was fixed as $1.00 \times 10^9$, minimum reduction in the error sum of squares was fixed at 0.001%, and the maximum allowed iterations was fixed at 50. Initial values of the parameters taken for the iteration are $\phi_1 = 0.39176$ and $\theta_1 = 0.21906$, and initial value for the Marquardat constant was taken as 0.001. After three iterations the decrease in the sum of squares was found to be less than 0.001 percent and then the iteration was terminated. The final estimates of the parameters and their significance are tabulated below.

Table : 5.2 Parameter estimates

| Parameter | Estimate | Standard error | t- value | Probability |
|---|---|---|---|---|
| $\phi_1$ | 0.463128 | 0.1031055 | 4.4918 | 0.000023 |
| $\theta_1$ | 0.4092497 | 0.13384124 | 3.0577 | 0.00301109 |

From the above table it can be seen that all the parameters are significant at 1% level of significance. The log likelihood for this estimate was found to be −742.1099. Correlation between the parameters is 0.27, which indicates that there is no collinearity between the estimates. The residual variance is estimated as 2748132.6. Using these estimates we can write the final fitted model as

$$y_t = 0.463128\,(y_{t-1} - y_{t-13}) + y_{t-12} + a_t - 0.4092497a_{t-12}. \qquad \ldots\ldots\ldots(5.3.2)$$

To test the conditions of stationarity and invertibility we have to find the roots of the characteristic polynomial equations $(1-\phi_1 B)=0$ and $(1-\theta_1 B^{12}) = 0$. The roots of the first equation lies out side the unit circles confirming that the fitted ARIMA model is stationary. For the model to be invertible, the roots of the polynomial equation $1- 0.4092497\ B^{12} = o$ should lie outside the unit circle.

To examine the suitability of fitted seasonal ARIMA model, the residual series were computed using the fitted model, and was used to compute the autocorrelations of the residual series. Plot of these autocorrelations is also made. The maximum absolute value of the observed autocorrelation for the residuals is at lag 10 and the value of the autocorrelation is 0.164 and its standard error is 0.101 which shows that this autocorrelation is not significant. The Box – Ljung $\psi^2$ statistic, to test whether the residuals behave like a white noise process, was computed using autocorrelations of the residuals upto lag 36, and the value is 26.393 which is found to be nonsignificant (p = 0.879). Hence the fitted model can be used as an approximation to the process which generated the time series data on marine export from Kerala. The observed series and the fitted model were drawn on the chart along with the confidence limits.

Autocorrelations of the original series (ACF), Partial autocorrelations of the original series (PACF), Behaviour of ACF and PACF of differenced series were worked out. Since model estimated is without constant term, means of the series have to be computed and included in the model as $y_t = (y_t - \mu)$.

## 5.4 Shrimp Export from Kerala

The model found suitable for shrimp export data is the seasonal ARIMA model, of the form $\phi(B)\,\Phi(B^s)\,\nabla^d \cdot \nabla_s^D y_t = \theta(B)\,\Theta(B^s)a_t$ where $\phi(B)$ is polynomial of degree p in B, $\Phi(B^s)$ is a polynomial of degree sp in B, $\nabla^d = (1-B)^d \nabla_s^D = (1-B^s)^D$, $\theta(B)$ is a polynomial in B of degree q, and $\Theta(B^s)$ is a polynomial in B of degree sq. For the present data, the order parameters were estimated as $p = 1, q = 0, d = 0, P = 0, D = 1$ and $Q = 0.1$. Before analysing the data it was centered and transformed by natural logarithm. Hence the model expression is

$(1-\phi_1 B)\,(1-B^{12})\,y_t = (1-\theta_1 B^{12})\,a_t$

*ie*, $y_t = \phi_1(y_{t-1} - y_{t-13}) + y_{t-12} + a_t - \theta_1 a_{t-12}$ -------------------------(5.3.3)

The estimates of the parameters of this model $\phi_1$, $\theta_1$ and the innovation variance were arrived at through iteration using SPSS. The initial values of the estimates used are $\phi_1 = 0.53345$ and $\theta_1 = 0.44488$. The iteration was terminated after 6 iterations when the decrease in the error sum of squares was found to be less than 0.001 percent. The final estimate of residual variance obtained is 0.15239662 and the final estimates of parameters are given in the following table.

Table 5.3 : Final parameter estimates

| Parameter | Estimate | Standard error | t-value | Probability |
|---|---|---|---|---|
| $\phi_1$ | 0.46365276 | 0.09339467 | 4.96 | .00000372 |
| $\theta_1$ | 0.66148358 | 0.12110013 | 5.46 | .000000050 |

From this table we can see that both the coefficients are significantly different from zero as indicated by the 't' test. ($p<0.01$ for both the parameters). Log-likelihood for the parameters final estimate is -42.810279. Correlation between the estimates of these parameters is very low, 0.0425 so that the estimates are not affected by collinearity. The expression for the model using the estimated values is

$$y_t = 0.46365276\,(y_{t-1} - y_{t-13}) + y_{t-12} + a_t - 0.66148358\,a_{t-1} - \quad \text{------------(5.4.1)}$$

The residual series were computed using the fitted model and further analyzed to test the existence of autocorrelations in the residual series. The autocorrelations of residuals were worked out on the chart. Highest autocorrelation was found at lag 14 which is −0.163 with standard error 0.098 and it is found to be nonsignificant. The Box-Ljung, $\chi^2$ statistic was computed using autocorrelations upto lag 36 of the residuals to test whether the residual series can be considered as a white noise series. The value of this $\chi^2$ is 16.726 which is also nonsignificant (p = 0.997).

Hence the estimated ARIMA (1,0,0) (0,1,1) model is suitable to represent the time series of shrimp export from Kerala. Using the estimated model, the expected values were computed and it is presented in the figure along with actual values of the time series and the confidence limits.

## 5.5 Shrimp Export from Kerala to Japan

Seasonal ARIMA model was considered for modelling this time series data. Initially two models were identified and estimated which appear to be suitable for this data. These models are

(i.) ARIMA (1,0,0) (0,1,1) and

(ii.) ARIMA (1,0,0) (1,1,1)

For the first model, the expression in terms of the time series is

$(1-\phi_1 B).(1-B^{12})\, y_t = (1-\theta_1 B^{12})\, a_t$ ----------------------------------(5.5.1)

*ie* $y_t = \phi_1(y_{t-1} - y_{t-13}) + y_{t-12} + a_t - \theta_1 a_{t-12}$ ----------------------(5.5.2)

and for the second model the expression is

$$(1-\phi_1 B).(1-\Phi_1 B^{12})\,(1-B^{12})\, y_t = (1-\theta_1 B^{12})\, a_t$$

$$\text{ie } (1-\phi_1 B - B^{12} + \phi_1 B^{13} - \Phi_1 B^{12} + \phi_1\Phi_1 B^{13} + B^{24} - \phi_1\Phi_1 B^{25}).y_t = (1-\theta_1 B^{12})\, a_t$$

so that we can express $y_t$ as

$$y_t = \phi_1(y_{t-1} - y_{t-13}) + (1 + \Phi_1)y_{t-12} - \phi_1\Phi_1(y_{t-13} - y_{t-25})$$
$$- y_{t-24} + a_t - \theta_1 a_{t-12}$$

The parameters of these models were estimated using SPSS software. For the first model initial values of the parameters were taken as 0.53477 and 0.2283 for $\phi_1$ and $\theta_1$ respectively. Iteration was carried out using Melard's algorithm for which the accuracy of the estimates was chosen as 0.001, minimum required reduction in residual sum of square was fixed as 0.001 percent. Marquardt constant was initially taken as 0.001 percent, and its maximum value was chosen as 1.0 x $10^{+9}$. Iteration was stopped after eight iterations, because the reduction in residual sum of squares was found to be less than 0.001 percent. Final estimates of the parameters of this model and other details are given in the table below.

**Table 5.4 : Parameter estimates**

| Parameter | Estimates | SE | t-value | Prob. |
|---|---|---|---|---|
| $\phi_1$ | 0.55324694 | 0.08971685 | 6.1665 | 0.00000002 |
| $\theta_1$ | 0.54025030 | 0.11483472 | 4.7046 | 0.00001025 |

Correlation between the estimates of the parameters is found to be 0.0765 which is very low indicating that the estimates are free from the problem of collinearity. Estimate of the innovation variance is 80425.84366. For these estimates the loglikelihood is -594.84366.

Using this estimated model, residuals were calculated and further analysed for checking the suitability of the model. Autocorrelations upto lag 36 were computed for the residual series along with standard errors and is shown in the Chart. Maximum autocorrelation is found at lag 24 and the value is –0.169 which is not significant. The Box – Ljung $\chi^2$ statistic computed using 36 autocorrelations of the residual series is 20.723 which is not significant (p = 0.980). This suggests that the estimated seasonal ARIMA (1,0,0) (0,1,1) model can be used to represent the time series of shrimp – export from Kerala to Japan.

For the second seasonal model identified for this time series, estimates of the parameters $\phi_1$, $\Phi_1$ and $\theta_1$ and the residual variance, the same set of initial values were chosen for the algorithm constants and the initial values taken for these parameters were $\phi_1 = 0.53477$, $\Phi_1 = 0.84981$ and $\theta_1 = 0.93336$. The algorithm was terminated after 14 iterations because the reduction in the residual sum of squares was less than 0.001 percent. The estimate of the residual variance is 68020.912. Final estimates of the parameters and their significance are shown below.

| Parameter | Estimates | SE | t-value | Prob. |
|---|---|---|---|---|
| $\phi_1$ | 0.56148537 | 0.0851411 | 6.595 | 0.0000 |
| $\Phi_1$ | 0.43445368 | 0.23321871 | 1.863 | 0.06610727 |
| $\theta_1$ | 0.98266349 | 2.5425752 | 0.3865 | 0.70015174 |

Here only the first parameter $\phi_1$ is significant at 5% level and others are not significant. Log-likelihood for these estimates is −592.87946. Correlation between the estimate of $\phi_1$ and that of $\Phi_1$ is 0.03639 and that between $\phi_1$ and $\theta_1$ is 0.068992. Though these two correlations are not signifcant, correlation between estimates of $\Phi_1$ and $\theta$ is significant and is equal to 0.82756. This may be due to the reason that these estimates are affected by the problem of collinearity. Also the conditions for invertibility are not well satisfied by these estimates.

Analysis of the residual series by computing autocorrelations upto lag 36 revealed that there are no significant autocorrelations between observations in the residual series. The Box-Ljung $\chi^2$ for the residual series using 36 auto correlations is 15.826 which is not significant (p=0.999). Though the residual analysis shows that the model can be used as an approximation for generating theoretical series, this model is rejected for the following reasons. (i) some of the coefficients in the model are non-significant (ii) the estimated model falls in the non-invertible region and (iii) the estimates of some of the parameters are corrupted due to high correlation existing between them. Hence the first model is most suited to this data. The model can be written as

$$y_t = 0.5532\,(y_{t-1} - y_{t-13}) + y_{t-12} + a_t - 0.5403\,a_{t-1} \text{ ----------(5.5.3)}$$

The observed values of the series and expected values using this model was computed.

## 5.6 Shrimp export from Kerala to US

The model identified for the shrimp export to US (data was subjected to log transformation to reduce variability) is the seasonal ARIMA model, ARIMA (2,0,0) (0,1,1). Its mathematical expression in terms of the back shift operator B, the centered and transformed shrimp export from Kerala to US time series data, $y_t$ and a white noise innovation series $a_t$ is

$$(1-\varphi_1 B - \varphi_2 B^2)\,(1-B^{12})\,y_t = (1 - \theta_1 B^{12})\,a_t$$

$$ie,\; y_t = \varphi_1(y_{t-1} - y_{t-13}) + \varphi_2\,(y_{t-2} - y_{t-14}) + y_{t-12} + a_t - \theta_1 a_{t-12} \text{ --(5.6.1)}$$

The parameters $\varphi_1$, $\varphi_2$, $\theta_1$ and the innovation variance $\sigma_a^2$ were estimated using SPSS software which is based on Milard's algorithm. For this Iterative algorithm, the initial estimates of the parameters were taken as 0.19648, 0.34214 and 0.53941 respectively. The constants to control the algorithm were fixed as follows. Accuracy of the parameters was fixed as 0.001, Marquardt constant was taken as 0.001; maximum value of this constant was fixed as $1.00 \times 10^9$ and the minimum reduction in the residual variance was fixed as 0.001 percent. With these values the algorithm for estimation was terminated after five iterations when the reduction in the residual sum of squares was found less than 0.001 percentage. The loglikelihood for the final estimate of the parameter is −61.693831 and the estimate of the innovation parameter is 0.23391592. Final estimates of the parameters of the model and other details are given below.

**Table 5.5 : Parameter estimates**

| Parameter | Estimate | S.Error | 't'- value | Probability |
|---|---|---|---|---|
| $\phi_1$ | 0.19749186 | 0.10090641 | 1.9571786 | .05377143 |
| $\phi_2$ | 0.25672185 | 0.10126709 | 2.5350965 | .01316576 |
| $\theta_1$ | 0.74508278 | 0.13258781 | 5.6195421 | .00000027 |

Except the parameter $\phi_1$ all other coefficients are significant and the correlation between estimates of these parameters are all low, with maximum between estimates of $\phi_1$ and $\phi_2$ being −0.2756. To examine the suitability of the fitted models, residual series was generated using the fitted model and the original series.

Autocorrelations between the residual upto lag36 were computed. Maximum autocorrelation was found at lag27 which is −0.178 and is nonsignificant. All the autocorrelations are nonsignificant. The Box-Ljung $\chi^2$ statistic using autocorrelation upto lag36 of the residual series is found to be 19.031 which is nonsignificant ($p=0.991$). Hence the fitted model is suitable as an approximation to the generating mechanism of the time series on shrimp exports from Kerala to United States. The final estimated model is

$$y_t = 0.1975\,(y_{t-1} - y_{t-13}) + 0.2567\,(y_{t-2} - y_{t-14}) + y_{t-12} + a_t - 0.7451\,a_{t-12}$$

The actual series, the expected values according to the model and their confidence limits were plotted.

## Reference


Anon. (1984). Production forecast. In Marine Fish Marketing in India.Vol. 4 Published by Central for Management in Agriculture. Indian Institute of Management, Ahamedabad.

Box, G.E.P. and Jenkins, G.M. (1976). Time series Analysis: Forecasting and Control ($2^{nd}$ Ed. ) Helden Day, San Francisco.

Bulmer, M.G. (1974). A statistical analysis of ten year cycle in Canada. J. Anim. Ecol. 43, 701-718.

Chakraborthy, D. (1973). An evaluation of marine fish resources of India. Proc. Symp. Living Seas around India. CMFRI, 223-229.

Dyer, T.G.J. and Giloly, J.F. (1979). Simulating fish production using exponential smoothing. Ecol. Model. 6, 77-87.

Fogary, M.J. (1988). Time series models of the Marine Lobster fishery: the effect of temperature. Can, J. Aquat. Sci. 45(7), 1145-1153.

Mendelssohn, R. (1980). Using Box-Jenkins models to forecast fishery dynamics. Identification, estimation and checking. Fishery Bulletin, United States. 78, 887-896.

Mongomery, D.C. and Johnson, L.A. (1976). Forecasting and time series analysis. Mc Graw – Hill Book Co., New York. pp.188.

Noble, A. and Sathyanandan, T.V. (1991). Trend analysis in all India Mackerel catches using ARIMA model. Ind. J. fish =. 38(2), 119-122.

Pankartz, A. (1983). Forecasting with univariate Box-Jenkins models. John Wiley and Sons, Include, New York, pp.562.

Saila, S.B. Wigbout, M. and Lermit, R.J. (1980). Comparison of some time series models for analysis of fisheries data. J. Cons. Ciem. 39, 44-52.

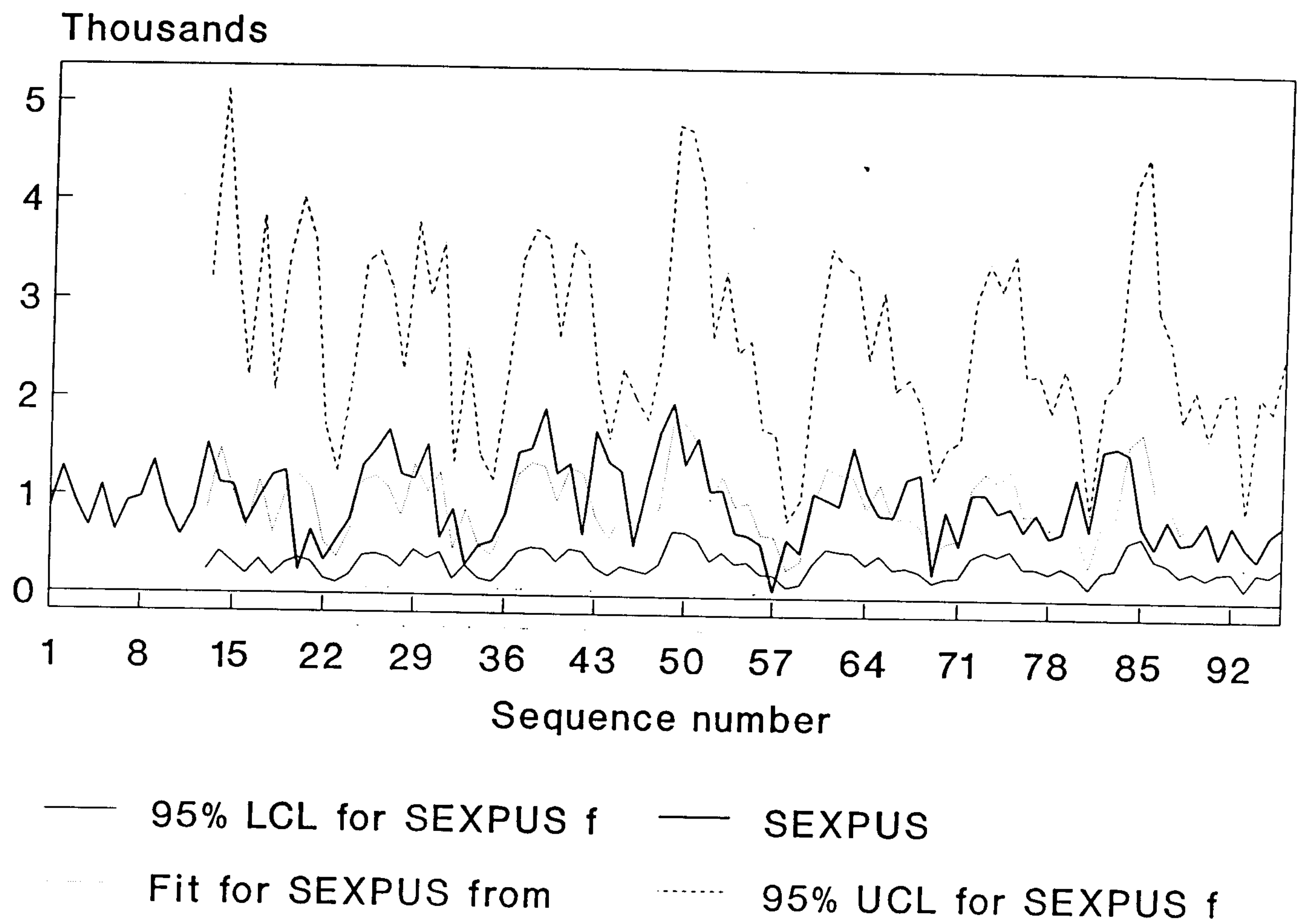
Shasthri, S.S. (1978). Trends in marine fish landings in India. Mahasagar. 11(12), 73-81.

Stergiou, K.I. (1990). An autoregressive model of fishery of anchovy, Engraulis encrasicoulus in the Eastern Mediteranian. Fish Bull. US. 88, 411-414.

Stocker, M and Hilborn, R. (1981). Short term forecasting in marine fish stocks, can. J. Fish. Aquat. Sci. 38, 1247-1254.

# Shrimp Export from Kerala to US

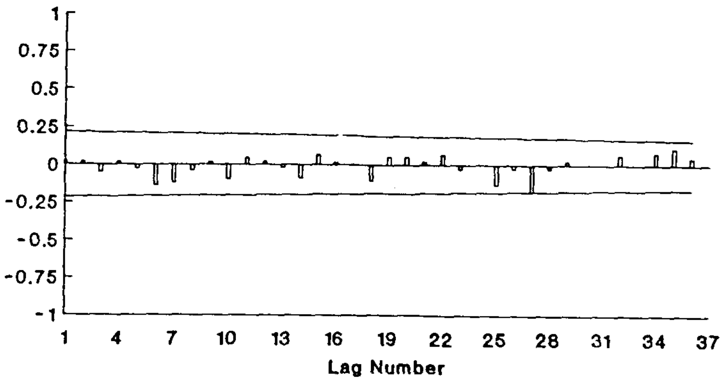
Chart-1




Model: ARIMA(2,0,0)(0,1,1)12 NOCONSTANT
on Ln of Export

chart-2

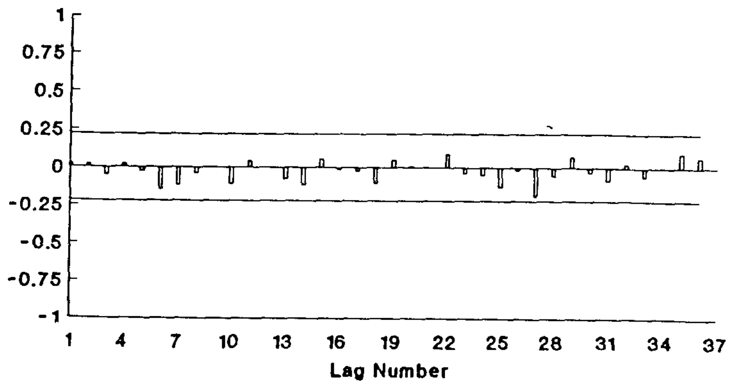
Shrimp export from Kerala to US
acf chart




Coefficients — Confidence Limits

Model: ARIMA(2,0,0)(0,1,1)12 NOCONSTANT
on LN of Export

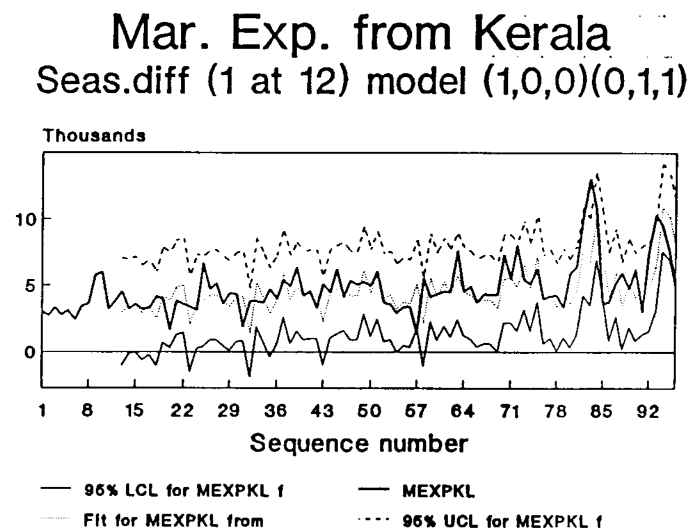
Shrimp export from Kerala to US
Error pacf chart



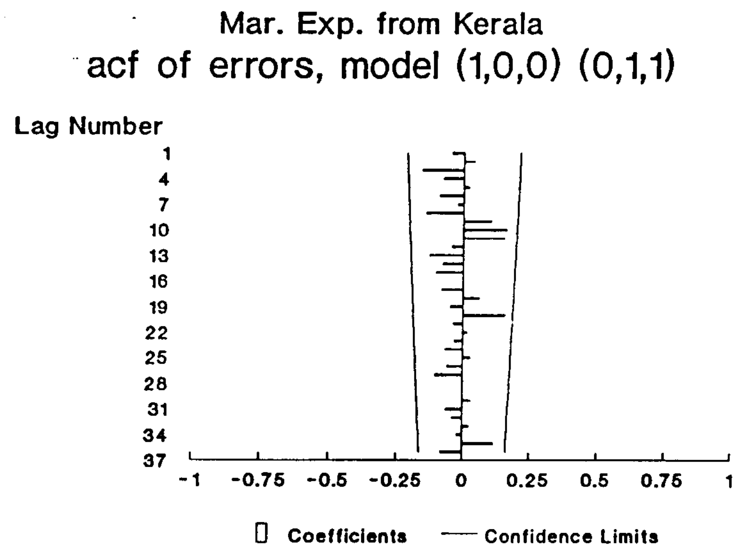

Coefficients — Confidence Limits

Model: ARIMA(2,0,0)(0,1,1)12 NOCONSTANT
on Ln of Export

chart-3



Mar. Exp. from Kerala
Seas.diff (1 at 12) model (1,0,0)(0,1,1)
Thousands
10
5
0
1 8 15 22 29 36 43 50 57 64 71 78 85 92
Sequence number
95% LCL for MEXPKL f
MEXPKL
Fit for MEXPKL from
95% UCL for MEXPKL f

Mar. Exp. from Kerala
acf of errors, model (1,0,0) (0,1,1)
Lag Number
1
4
7
10
13
16
19
22
25
28
31
34
37
-1 -0.75 -0.5 -0.25 0 0.25 0.5 0.75 1
Coefficients
Confidence Limits

Chart-4

# Mar. Export from Kerala
## pacf of errors, model (1,0,0) (0,1,1)

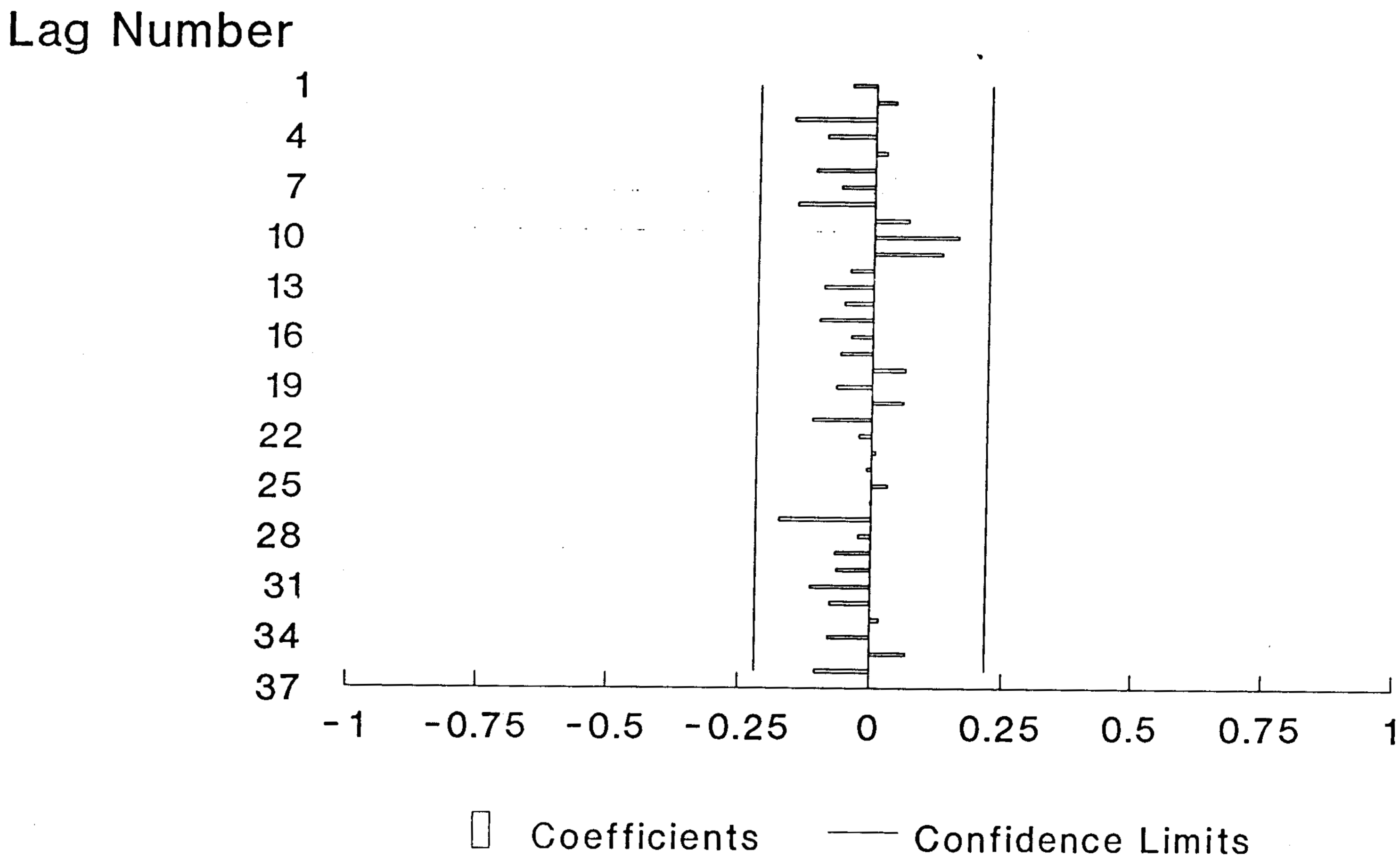
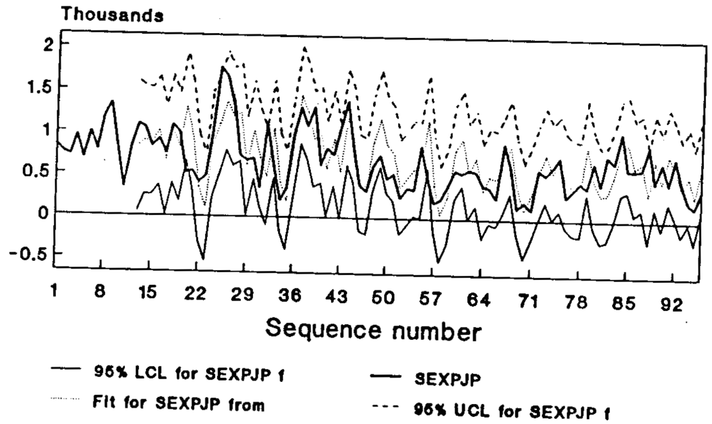
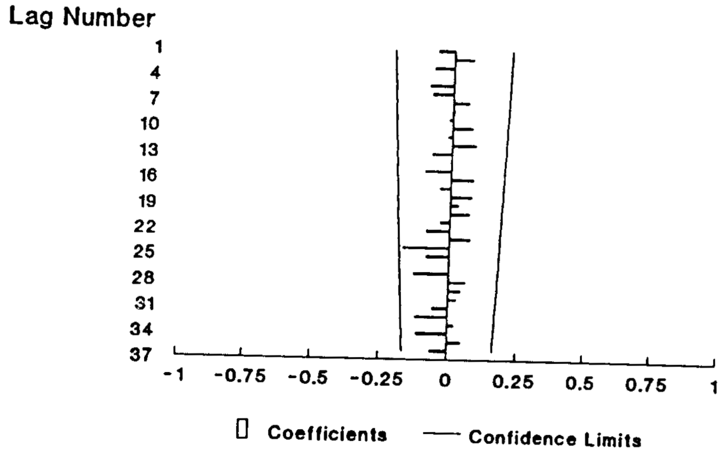


chart-5

## Shrimp export from Kerala to Jap
### Diff.(1 at 12), model (1,0,0) (0,1,1)




## Shrimp export to Japan
### Error ACF Chart, model (1,0,0) (0,1,1)



# CONCLUSION

With a view of enhancing the understanding of Fishery in Kerala a humble attempt is made to explain the interrelations between a few important economic parameters of the fishery in Kerala and the results are presented in the last five chapters. The main objectives of this attempt are to study the contribution of fisheries sector to the economy of Kerala using time series and regression models; to investigate the trends in marine fish production over years employing suitable growth models; to assess the marine fisheries resources for optimum exploitation of prawn species using different approaches; to study the effect of environmental parameters on the fishery and to study the trend in marine product export from Kerala employing ARIMA models for short term forecasting.

In the first chapter the interrelations between various economic indicators are studied. The contribution from the fishing sector to the state economy, to the primary, secondary and tertiary sectors are examined. Growth of State Domestic Product, Fishing Industry and Primary Sector over years are analysed using time series model. The effect of marine and inland catches on fishing income is presented using regression models. Forecasting of fishing income also is attempted. Percapita output, percapita income etc. are also investigated.

Trends of fish landings are studied using suitable growth models. Logistic, Gompertz, Malthus, Exponential and Bass models are used for formulation of models. The catch and effort statistics for the Kerala coast are presented using synthetic models. The optimum level of fishing efforts and maximum sustainable catch for conservation of fishery resources using latest statistics are obtained. Schaefer, Fox models are applied apart from hyperbolic and power models. Study on economics of operation of fishing trawlers reveals that the trawl fishing is profitable to the tune of 26 percent. The effect of environmental factors on the fishery is presented using appropriate models in the fourth chapter. By the application of ARIMA models the trend analysis of the marine product exports from Kerala is studied for total marine products, frozen shrimp, and exports to USA and Japan. In all these approaches models of good fit were formulated which can be used for forecasting. It is hoped that the findings will be of some help to researchers and policy makers for evolving suitable fishery management decisions for sustained development of the fishery in Kerala.