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# Impact of introduction of crafts with outboard engines on marine fish production in Kerala and Karnataka – a study through Intervention analysis.

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## ABSTRACT

In the recent years, the contribution from outboard sector is a major component in the total marine fish production from the states of Kerala and Karnataka. This is as a result of the introduction of crafts fitted with outboard engines for propulsion in the mid eighties, which intensified and developed into a major sector. The impact of this intervention is examined here by adopting two popular time series methods used for intervention analysis. The first method is based on seasonal *ARIMA* modeling and the second is based on regression modeling with *ARMA* type errors. Quarterwise total marine fish landings in the two states during 1960-2000 were used for the impact study. The analysis revealed that for Kerala the model found suitable is seasonal *ARIMA* type model and for Karnataka the feasible model was regression model with *ARMA* errors. Based on the final estimated intervention models, the effect of the interventions was estimateds as 2.26 lakh tonnes and 88 thousand tonnes per annum respectively for Kerala and Karnataka.

## Introduction

Among the maritime states in India, Kerala has a prominent place with regard to marine fish production in the country, contributing to almost 25% of the total marine fish production, though the total coastline is about one-tenth of the Indian coastline. In the year 2000, total marine fish production from Kerala was 6.04 lakh tonnes, which accounts for 22.49 % of the total marine fish production in the country. Karnataka ranks sixth among the maritime states of India with respect to total marine fish production. During the year 2000,the total marine fish production from Karnataka was 1.82 lakh tonnes, representing 6.9 % of the all India production.

Introduction of outboard engines in the mid eighties for propulsion was one of the significant technological changes in the fishery of both Kerala and Karnataka. Country crafts started using imported outboard engines for propulsion, which intensified over years and by 1988, it became a significant sector in these states. This period also witnessed introduction of an efficient gear namely "ring seine" operated exclusively by these motorized units. A change in the regime of landings in these two states occurred due to this intervention. Intervention can be interpreted as the occurrence of an exogenous event, which exerts its influence on the historical behavior of a variable. It could be a change in policy, introduction of a new technology or enforcement of certain restrictions (Valle 2002). The contribution from outboard sector in 2000 is 3,47,329 tonnes (57.49%) for Kerala and 15,465 tonnes (8.45%) for Karnataka.

This study aims at estimation of effects of this intervention, namely introduction of outboard engines together with "ring seine" operation in to the fisheries sector, on marine fish landings, in the states of Kerala and Karnataka through intervention analysis by modelling quarter wise total marine fish landings in the two states during the period 1960-2000. Two different approaches in time series modelling for intervention analysis are adopted for the study. The first approach is based on seasonal AutoRegressive Integrated Moving Average (*ARIMA*) modelling and the second is based on regression modelling with *ARMA* type errors.

Time series techniques are widely used in fisheries research. Different authors have used time series methods for analysing fisheries data. Saila (1980) analysed monthly average catch per day of rock lobster from New Zealand using monthly averages, harmonic regression and *ARIMA* models. Stocker and Hilborn (1981) considered stock production models and time series models for short term forecasting of marine fish stocks. Jensen (1985) analysed the catch and catch per unit effort data for Atlantic menhaden and Gulf menhaden through autocorrelation analysis to test for time lags and also to develop forecasting models. Srinath and Datta (1985) used *ARIMA* models for forecasting marine products export from India. Misra and Uthe (1987) applied time trends analysis to contaminant levels in Canadian Atlantic cod and illustrated the use of MANOCOVA for time series trends investigation. Stergiou (1989) analyzed monthly catches of pilchard from Greek waters using autoregressive integrated moving average models and identified two models for describing the dynamics of the fishery and forecasting. Noble and Sathianandan (1991) used autoregressive integrated moving average models to study the trend in all India mackerel catches. Sathianandan and Alagaraja (1998) studied all India annual landings of oil sardine, mackerel and Bombay duck using spectral analysis to bring out inherent periodicity in these time series. Sathianandan and Srinath (1995) carried out time series analysis of marine fish landings in India for modelling using *ARIMA* models.

Intervention analysis is a well-known technique in time series analysis that is used to examine the effect on the time series of certain interventions. Bhattacharyya (1979) modified the Box-Jenkins univariate time series model to incorporate intervention effects for a case study on effectiveness of seat belt legislation on the Queensland road toll through intervention analysis and using this model he could quantify the long run legislative effect as a reduction of 46% in road deaths. Abraham (1980) presented a general model to encapsulate interventions in multiple time series and described the estimation procedure. Harvey and Durbin (1986) also conducted a case study in structural time series modelling to examine the effect of seat belt legislation on British road casualties.

Noakes (1986) used Moving average model of order 1 with an additional intervention component to quantify changes in British Columbia Dungeness crab (*Cancer magister*) landings using intervention analysis. Sridharan, *et. al*. (2003) examined the impact of sentence reforms in Virginia on reported crime rates using structural time series approach to intervention analysis.

## Materials and methods

The data for the study were obtained from the "National Marine Living Resources Data Centre" of the Central Marine Fisheries Research Institute at Cochin, Kerala. Quarter wise total marine fish landings in Kerala and Karnataka during the period 1960-2000 was used for the analysis. To study the intervention and estimate its effect two separate approaches were adopted in this study. In the first approach we use a method based on seasonal *ARIMA* modelling. The intervention model is given by

$I_t$

$$y_{t=} \; \delta \quad +u_t \qquad (1)$$

where $y_t$ is the time series sequence, is the intervention coefficient $I_t$, is an auxiliary variable that takes the value 0 for the period before intervention and 1 on and after the intervention and $u_1$ has the structure of a seasonal *ARIMA* model denoted by *ARIMA(p,d,q)(P,D,Q)s* with order of autoregression (*AR*) *p*, order of differencing *d*, moving average (*MA*) order *q*, seasonal *AR* order *P*, order of seasonal differencing *D*, seasonal *MA*

$$\varphi(B^s)\,\phi(B)\,\nabla^d\,\nabla_s^D\,u_t = \Theta(B^s)\,\theta(B)\,\varepsilon_t \qquad (2)$$

order *Q* and seasonality *s*. The seasonal *ARIMA* model expression is

The back shift operator *B* is such that.

$$\Delta = 1 - B$$

$$\Delta_s = 1 - B^s$$

$$\phi(B) = 1 - \phi_1 B - \cdots - \phi_p B^p$$

$$\varphi(B^s) = 1 - \varphi_1 B^s - \cdots \varphi_P B^{sP}$$

$$\theta(B) = 1 - \theta_1 B - \cdots - \theta_q B^q$$

$$\Theta(B^s) = 1 - \Theta_1 B^s - \cdots - \Theta_Q B^{sQ}$$

Other terms in the model have the following meanings.

and $\varepsilon_\tau$'s are independently and identically distributed random variables with 0 mean and constant variance $\sigma^2$, which represents the error term in the model. The data used for the analysis being quarterly data, seasonality for the model was taken as 4.

$$y_t = \alpha + \beta' x_t + \delta\ I_t + u_t \qquad (3)$$

The second approach is based on regression model with ARMA errors which is given by

$$\phi(B) u_t = \theta(B) \varepsilon_t \quad (4)$$

Here also $\delta$ represents the intervention coefficient, *a* is a constant term, $x_t$ is a vector of explanatory variables and $\beta$ is the corresponding vector of regression coefficients. All other terms in the model have similar meaning as in the first approach. Spectral components were used as explanatory variables in this study to account for the trend and seasonality present in the data. Frequencies for the spectral components were determined by computing periodogram for the series.

For estimation of parameters of the model the "trends" module in *SPSS* software was used. The algorithm used in this module for ARIMA estimation is the one given by Melard (1984), which is a fast algorithm for calculating exact likelihood of a stationary *ARMA* model, that uses a modified Kalman filter recursion based on a state-space representation of the model. For testing adequacy of estimated models the statistic Q given by Ljung and Box (1978), based on the autocorrelations of the residuals was used. The test statistic Q is given by

$$Q = T(T+2)\sum_{k=1}^{m}[r_k^2/(T-k)] \quad (5)$$

where $r_k$ is the autocorrlation of lag $k$ of the residuals and T is the sample size. The test statistic Q has ÷² distribution with ($m$-$p$-$q$) degrees of freedom where $m$ is the number of residual autocorrelations used for the calculation (48 in this study) and $p$ and $q$ are the orders of the model fitted.

For identification of orders of *ARMA* models, the popular minimization criterion proposed by Akaike (1972) known as *AIC* criterion and the Bayesian Information Criterion proposed by Schwartz (1978), known as *SBC* were used. The *AIC* = $1n(\sigma^2_r)+2r/T$ criterion is defined as and the *SBC* criterion is given by *BIC(r)* = $1n(\sigma^2_r)+rn(T)/(T)$ where $\sigma^2_r$ is the maximum likelihood estimate of the innovation variance, $r$ is the number of parameters in the model and $T$ is the size of the sample series.

## Results

### *Intervention models for Kerala*

The quarter wise total marine fish landings in Kerala fluctuated between 12.7 thousand tonnes (second quarter of 1962) and 2.23 lakh tonnes (third quarter of 1994). The maximum annual landings observed during this period was 6.63 lakh tonnes in 1990 and the minimum was 1.92 lakh tonnes in 1962. The average annual landings during the period 1960-87 (before intervention) was 3.39 lakh tonnes and that for the period 1988-2000 (after intervention) was 5.73 lakh tonnes. This indicates an increase of about 40% in the annual landings during second phase compared to the first. The average quarter wise landing for the whole period is 1.03 lakh tonnes with a standard deviation of about 48.4 thousand tonnes. A brief summary of the averages and standard deviations for the total marine fish landings in Kerala for the two phases are given in Table-1 and a plot of the quarter wise landings along with pre and post intervention means are given Fig.1.

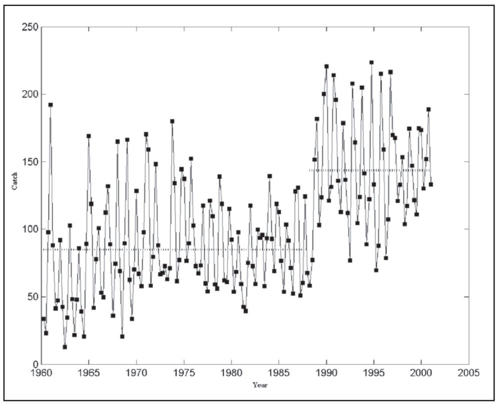


Fig.1. Quarter wise total marine fish landings (x 1000 tonnes) in Kerala during 1960-2000 with estimated pre and post intervention means (horizontal dotted lines).

### *Seasonal ARMA modeling*

For seasonal *ARIMA* modelling, the time series on quarter wise total marine fish landings in the state during 1960-2000 was standardized to have zero mean and unit variance. Based on the *AIC* and *SBC* criteria the seasonal model selected for the series was *ARIMA* (*0,1,2*)(*0,1,1*)*4*. Estimates of parameters of the model, standard errors of the estimates, residual variance ($\sigma^2$), *AIC* and *SBC* values and the Box-Ljung $x^2$ statistic based on residual autocorrelations up to lag 48 for testing adequacy of the model are given

TABLE 1: *Average landings (x 1000 tonnes) and coefficient of variation in landings of Kerala and Karnataka for different quarters before and after the intervention.*

| | Kerala | | | | Karnataka | | | |
|---|---|---|---|---|---|---|---|---|
| | 1960-87 | | 1988-2000 | | 1960-87 | | 1988-2000 | |
| Quarter | Mean | CV | Mean | CV | Mean | CV | Mean | CV |
| I | 70.36 | 36.30 | 107.36 | 26.33 | 31.10 | 79.50 | 47.08 | 24.36 |
| II | 50.71 | 37.23 | 112.66 | 18.29 | 12.27 | 103.56 | 23.05 | 27.43 |
| III | 98.28 | 33.33 | 190.94 | 13.77 | 15.56 | 124.78 | 36.68 | 20.17 |
| IV | 119.68 | 27.48 | 162.34 | 15.45 | 55.77 | 52.01 | 68.42 | 24.88 |
| Overall | 84.76 | 45.43 | 143.33 | 30.02 | 28.67 | 98.21 | 43.81 | 45.86 |

in Table-2. Estimates of all the three parameters of the model are significant, residual autocorrelations up to lag 48 were all not significant and $x^2$ the test statistic is non-significant indicating that the estimated model is very much suitable for the time series. This model explained 68% of the variations in the time series data. To develop the intervention model, using this series up to 1987 (period prior to intervention), a suitable seasonal ARIMA model was identified in a similar manner based on *AIC* and *SBC* criteria. The model selected for this time series was *ARIMA* (*0,0,1*)(*0,1,1*)*4*. Estimates of parameters and other details for this model are given in Table-2. For this model also all the parameter estimates are significant and it explained almost 66% of the variations in the time series. Residual auto-correlations generated based on this model were not significant up to lag 48 and the Box-Ljung test statistic was also not significant. Hence this model is suitable to adequately represent the time series.

Keeping the same model and an additional auxiliary variable, to represent the intervention part by defining it to take zero values before intervention period and unity on and after, the model was re-estimated by using the entire series from 1960 to 2000. The re-estimated parameters of the model and other details are given in Table-2 for the intervention model. Here also, all the parameter estimates are significant and the model explained about 72% of the variations in the entire time series. The estimate of the regression coefficient corresponding to the newly added auxiliary variable is also significant and it gives a measure of the effect of the intervention on the time series. Comparing this model with the first seasonal *ARIMA* model, by incorporating the intervention component into the model we are able to explain additional 4% of the variations in the data. The effect of intervention was calculated from the estimated regression coefficient corresponding to the auxiliary variable by converting it into the original scale. It showed that on an average there is an increase of about 2.26 lakh tonnes in annual total marine fish landings in Kerala due to the intervention – that is by the introduction of outboard sector.

***Regression model with ARMA errors***

To estimate the frequencies for prominent spectra in the standardized series on quarter wise landings in Kerala during 1960-2000, periodogram was computed and its plot is given in Fig-3. The two frequencies $\lambda_1$=0.25 and $\lambda_2$=0.00893 corresponding to the major two spectral components were considered for inclusion in the model. At the model selection stage, components with frequency $\lambda_2$=0.00893 were not found significant when included in the model

TABLE 2: *Estimates of parameters, standard errors, AIC and SBC values, Box-Ljung* $\chi^2$ *and significance probabilities for different seasonal ARIMA and intervention model fitted for quarter wise landings series of Kerala.*

| Model | Data used | Parameters / test statistic | Estimate | Standard Error | AIC & SBC |
|---|---|---|---|---|---|
| *ARIMA* (*0,1,2*)(*0,1,1*) | 1960-2000 | $(1-B^4)(1-B)\,y_t=(1-\Theta_1 B^4)(1-\theta_1 B-\theta_2 B^2)\,\varepsilon_t$ | | | |
| | | $\theta_1$ | 0.444058 | 0.072103 | 279.52 |
| | | $\theta_2$ | 0.436323 | 0.074475 | 288.72 |
| | | $\Theta_1$ | 0.762603 | 0.061130 | |
| | | $\sigma^2$ | 0.3199 | | |
| | | $\chi^2$ | 41.873 *(p =0 .721)* | | |
| *ARIMA* (*0,0,1*)(*0,1,1*) | 1960-87 | $(1-B^4)\,y_t=(1-\Theta_1 B^4)(1-\theta_1 B)\,\varepsilon_t$ | | | |
| | | $\theta_1$ | -0.535548 | 0.083424 | 172.29 |
| | | $\Theta_1$ | 0.747193 | 0.071686 | 177.66 |
| | | $\sigma^2$ | 0.2737 | | |
| | | $\chi^2$ | 39.753 *(p =0 .796)* | | |
| *Intervention model* | 1960-2000 | $y_t = \delta\, I_t + u_t$ with $(1-B^4)\,u_t=(1-\Theta_1 B^4)(1-\theta_1 B)\,\varepsilon_t$ | | | |
| | | $\theta_1$ | -0.458174 | 0.070680 | 259.22 |
| | | $\Theta_1$ | 0.763580 | 0.55155 | 268.45 |
| | | $\delta$ | 1.166559 | 0.242727 | |
| | | $\sigma^2$ | 0.2836 | | |

for the entire series and hence excluded from the final model for the entire series. The regression model thus selected based on *AIC* and *SBC* criteria for the entire series is of the form

$$y_t = \beta_1\, x_1 + \beta_2\, x_2 + \eta_t \quad (6)$$

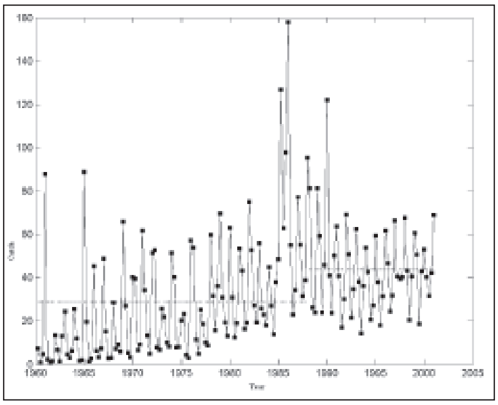

Fig.2. Quarter wise total marine fish landings (x1000 tonnes) in Karnataka during 1960-2000 with estimated pre and post intervention means (horizontal lines).

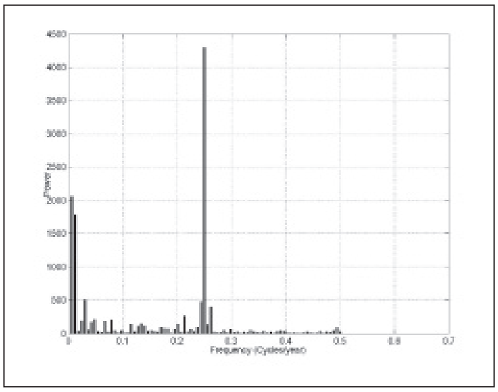

Fig.3. Periodogram plot of standardized series on quarter wise marine fish landings in Kerala 1960-2000.

with, $x_1$=*Cos* $(2\pi\lambda_1 t)$, $x_2$=*Sin* $(2\pi\lambda_1 t)$, $\lambda_1$=0.25 and $\eta_1$ is an *ARMA(4,0)* process. The final model selected based on *AIC* and *SBC* for the pre-intervention period of this series is

$$y_t = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \eta_t \quad (7)$$

where *a* is a constant term, $x_1$=*Cos* $(2\pi\lambda_1 t)$, $x_2$=*Sin*$(2\pi\lambda_1 t)$, $x_3$=*Cos* $(2\pi\lambda_2 t)$, $\lambda_1$=0.25, $\lambda_2$=*0.00893* and $\eta_1$ an *ARMA(2,0)* process. The intervention model used for modeling the entire series is

$$y_t = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \delta I_t + \eta_t \quad (8)$$

where the terms are same as in (7) except for and which are explained in (1). Estimates of parameters, standard errors of the estimates, values of the selection criteria, Box-Ljung and other details for the above three models are given in Table 3.

In model (6) fitted for the entire series all the parameters except $\varnothing_1$and $\varnothing_2$ of *ARMA(4,0)*, are significant. This model explained about 67% of the variations in this time series and the residual analysis by using residual autocorrelations up to lag 48 showed no significant autocorrelations. Box-Ljung $x^2$ statistic was non-significant indicating adequacy of the fitted model. All the parameter estimates of the model (7) for the pre-intervention period were significant and none of the residual autocorrelations for this model was significant. The Box-Ljung $x^2$ statistic was also non-significant indicating suitability of the model for the pre-intervention series. This model explained 65% of the variations in pre-intervention series. Using this model and incorporating the intervention term, the model parameters were estimated again and this model (8) explained 69% of the variations in the entire series. Hence, the regression with ARMA errors type modeling the intervention model could explain 2% more variations than the first model. Based on the estimate of intervention parameter $\delta$, the effect of intervention was calculated and it was found to be 2.38 lakh tonnes in annual total marine fish landings of Kerala.

### *Intervention models for Karnataka*

The average landings in Karnataka during 1960-1987 was 1.03 lakh tonnes and that during 1988-2000 was 1.75 lakh tonnes. There is an increase of 70% in the second phase compared to the first phase. The average quarter-wise landings for the whole period was 33.5 thousand tonnes with a standard deviation of 26.9 thousand tonnes. Table-1 gives the details of the averages and standard deviations in the total marine fish landings of Karnataka for different quarters before and after the intervention. Plot of the quarter wise landings with pre and post intervention means is given in Fig.2.

### *Seasonal ARMA modelling*

The standardized series on quarter wise landings in Karnataka during 1960-2000 was used for fitting the seasonal *ARIMA* model. The model selected based on the *AIC* and *SBC* criteria for this series is *ARIMA (0,1,1)(1,1,1)*. Estimates of parameters of the model, standard errors of the estimates and other details for this model are given in Table-4. All the parameter estimates were found significant and the $x^2$ test statistic was non-significant. None of the residual autocorrelations up to lag 48 were significant. Hence this model is a suitable representation of the series and it explained 60% of the variations in the series. Using the series for the pre-intervention period, the seasonal *ARIMA* model identified based on AIC and SBC criteria is *ARIMA (0,0,1)(0,1,1) 4*. Estimates of parameters and other details for this model are given in Table-4. All the

TABLE 3: *Estimates of parameters, standard errors, AIC and SBC values, Box-Ljung $\chi^2$ and significance probabilities for different regression type models and intervention model fitted for quarter wise landings series of Kerala.*

| Model | Data used | Parameters / test statistic | Estimate | Standard Error | AIC & SBC |
|---|---|---|---|---|---|
| | | | $y_t = \beta_1 x_1 + \beta_2 x_2 + \eta_t$ with $(1-\phi_1 B - \phi_2 B^2 - \phi_3 B^3 - \phi_4 B^4)\eta_t = \varepsilon_t$ | | |
| *ARIMA (4.0)* for error term | 1960-2000 | $\varnothing_1$ | 0.479683 | 0.074572 | 293.26 |
| | | $\varnothing_2$ | -0.133926 | 0.083426 | 311.86 |
| | | $\varnothing_3$ | 0.139911 | 0.083631 | |
| | | $\varnothing_4$ | 0.356333 | 0.075332 | |
| | | $\beta_1$ | -0.0487449 | 0.102824 | |
| | | $\beta_2$ | -0.644.92 | 0.102884 | |
| | | $\sigma^2$ | 0.3346 | | |
| | | $\chi^2$ | 54.843 (p=0.231) | | |
| | | | $y_t = \alpha + \sum_{i=1}^{3} \beta_i x_i + \eta_t$ with $(1-\phi_1 B - \phi_2 B^2)\eta_t = \varepsilon_t$ | | |
| *ARIMA* for error term | 1960-87 | $\varnothing_1$ | 0.401722 | 0.095552 | 180.64 |
| | | $\varnothing_2$ | -0.267106 | 0.096156 | 196.95 |
| | | $\alpha$ | -0.386684 | 0.057637 | |
| | | $\beta_1$ | -0.302142 | 0.084039 | |
| | | $\beta_2$ | -0.710078 | 0.084039 | |
| | | $\beta_3$ | -0.228447 | 0.081719 | |
| | | $\sigma^2$ | 0.2778 | | |
| | | $\chi^2$ | 38.211 *(p=0.843)* | | |
| | | | $y_t = \alpha + \sum_{i=1}^{3} \beta_i x_i + \delta I_t + \eta_t$ with $(1-\phi_1 B - \phi_2 B^2)\eta_t = \varepsilon_t$ | | |
| *Intervention model* | 1960-2000 | $\varnothing_1$ | 0.342105 | 0.077700 | 283.04 |
| | | $\varnothing_2$ | -0.272006 | 0.077694 | 304.74 |
| | | $\alpha$ | -0.385222 | 0.057095 | |
| | | $\beta_1$ | -0.478168 | 0.076826 | |
| | | $\beta_2$ | -0.645486 | 0.076826 | |
| | | $\beta_3$ | -0.149117 | 0.067898 | |
| | | $\delta$ | -1.2280367 | 0.101832 | |
| | | $\sigma^2$ | 0.3147 | | |

parameter estimates for this model are significant and the model explained almost 57% of the variations in the time series. Residual autocorrelations generated based on this model were not significant up to lag 48 and the Box-Ljung $x^2$ test statistic was also not significant. Hence this model was chosen as the suitable model for the pre-intervention period time series. Using this model and also the additional auxiliary variable to account for the intervention, the model parameters were re-estimated by using the entire series and details regarding parameter estimates are given in Table.4. But, when re-estimated, the model failed to give a significant estimate of the intervention effect.

## *Regression model with ARMA errors*

To estimate the frequencies for

TABLE 4: *Estimates of parameters, standard errors, AIC and SBC values, Box-Ljung $\chi^2$ and significance probabilities for different seasonal ARIMA and intervention model fitted for quarter wise landings series of Karnataka.*

| Model | Data used | Parameters / test statistic | Estimate | Standard Error | AIC & SBC |
|---|---|---|---|---|---|
| *ARIMA (0,1,1) (1,1,1)* | 1960-2000 | $(1-B)(1-\Phi_1 B^4)(1-B^4)\,y_t=(1-\Theta_1 B^4)(1-\theta_1 B)\,\varepsilon_t$ | | | |
| | | $\theta_1$ | 0.687693 | 0.060697 | 320.13 |
| | | $\Phi_1$ | -0.184953 | 0.087707 | 329.34 |
| | | $\Theta_1$ | 0.900839 | 0.050278 | |
| | | $\sigma^2$ | 0.405801 | | |
| | | $\chi^2$ | 37.97 *(p=0.850)* | | |
| *ARIMA (1,0,0) (O,1,1)* | *1960- 1987* | $(1-\phi_1 B)(1-B^4)y_t=(1-\Theta_1 B^4)\,\varepsilon_t$ | | | |
| | | $\varnothing_1$ | 0.430923 | 0.090462 | 226.46 |
| | | $\Theta_1$ | 0.802485 | 0.076521 | 231.82 |
| | | $\sigma^2$ | 0.449679 | | |
| | | $\chi^2$ | 29.023 *(p=0.986)* | | |
| *Intervention model (1,0,0) (0,1,1)* | *1960-2000* | $y_t=\delta I_t+u_t$, $(1-\phi_1 B)(1-B^4)u_t=(1-\Theta_1 B^4)\,\varepsilon_t$ | | | |
| | | $\varnothing_1$ | 0.398677 | 0.075169 | 315.66 |
| | | $\Theta_1$ | 0.806554 | 0.056856 | 324.89 |
| | | $\delta$ | -0.003793 | 0.296816 | |
| | | $\sigma^2$ | 0.4022 | | |

prominent spectra in the standardized series on quarter wise landings in Karnataka, periodogram was computed and its plot is given in Fig-4. Based on the periodogram three frequencies, $\lambda_1$=0.25, $\lambda_1$=0.00893 and $\lambda_3$=0.01786 were chosen for inclusion of spectral components as regressors in the model. At the identification stage of this series, it was observed that in the models that minimize the selection criteria, the components corresponding to frequencies $\lambda_2$=0.00893 and $\lambda_3$=0.01786, were not significant. Hence the reduced model (9) was used for this series.

$$Y_1=\beta_1X_1+\beta_2X_2+\eta_t \quad (9)$$

The model selected based on AIC and SBC criteria is with *ARMA(2,2)* for the error term. The final model selected based on order selection criteria for the pre-intervention period of this series is

$$y_t=\alpha+\sum_{i=1}^{5}\beta_i\,x_i+\eta_t \quad (10)$$

where is a constant term,

$x_1=Cos(2\pi\lambda_1 t)$, $x_2=Sin(2\pi\lambda_1 t)$, $x_3=Cos(2\pi\lambda_2 t)$, $x_4=Sin(2\pi\lambda_2 t)$, $x_5=Sin(2\pi\lambda_3 t)$, and $\eta_t$ is an *ARMA (2,2)* process. The intervention model used for modelling the entire standardized series is

$$y_t=\alpha+\sum_{i=1}^{5}\beta_i\,x_i+\delta\,I_t+\eta_t \quad (11)$$

where the terms are same as in (10) except for and which are as explained in (1). Estimates of parameters, standard errors of the estimates, values of the selection criteria, Box-Ljung and other details for the above three models are given in Table-5.

In model (9) fitted for the entire series all the parameters except of *ARMA (2,2)*, are significant. This model explained around 53% of the variations in this time series and the residual analysis by computing residual autocorrelations up to lag 48 showed no significant autocorrelations. Box-Ljungstatistic was non-

Table 5: *Estimates of parameters, standard errors, AIC and SBC values, Box-Ljung* $\chi^2$ *and significance probabilities for different regression type models and intervention model fitted for quarter wise landings series of Karnataka.*

| Model | Data used | Parameters / test statistic | Estimate | Standard Error | AIC & SBC |
|---|---|---|---|---|---|
| *ARMA* (*2,2*) for error term | 1960-2000 | $y_t = \beta_1 x_1 + \beta_2 x_2 + \eta_t$ with $(1-\phi_1 B - \phi_2 B^2)(1-\theta_1 B - \theta_2 B^2)\eta_t = \varepsilon_t$ | | | |
| | | $\varnothing_1$ | -0.133363 | 0.072366 | 241.78 |
| | | $\varnothing_2$ | 0.863902 | 0.072597 | 258.09 |
| | | $\theta_1$ | -0.527916 | 0.129727 | |
| | | $\theta_2$ | 0.441162 | 0.130458 | |
| | | $\beta_1$ | 0.303671 | 0.075615 | |
| | | $\beta_2$ | -0.79869 | 0.075615 | |
| | | $\sigma^2$ | 0.4723 | | |
| | | $x^2$ | 34.645 *(p=.926)* | | |
| *ARIMA (1,0,0) (O,1,1)* | *1960- 1987* | $y_t = \alpha + \sum_{i=1}^{5} \beta_i x_i + \eta_t$ with $(1-\phi_1 B - \phi_2 B^2)\eta_t = \varepsilon_t$ | | | |
| | | $\varnothing_1$ | 0.214223 | 0.094938 | 244.81 |
| | | $\varnothing_2$ | 0.268009 | 0.095798 | 266.56 |
| | | $\alpha$ | -0.179240 | 0.125441 | |
| | | $\beta_1$ | 0.299882 | 0.072585 | |
| | | $\beta_2$ | -0.800487 | 0.072585 | |
| | | $\beta_3$ | 0.246223 | 0.174034 | |
| | | $\beta_4$ | -0.430916 | 0.178313 | |
| | | $\beta_5$ | -0.388662 | 0.174709 | |
| | | $\sigma^2$ | 0.4841 | | |
| | | $x^2$ | 45.128 (*p=0.591*) | | |
| *Intervention model* | *1960-2000* | $y_t = \alpha + \sum_{i=1}^{5} \beta_i x_i + \delta I_t + \eta_t$ with $(1-\phi_1 B - \phi_2 B^2)\eta_t = \varepsilon_t$ | | | |
| | | $\varnothing_1$ | 0.199146 | 0.078339 | 318.85 |
| | | $\varnothing_2$ | 0.208262 | 0.078753 | 346.69 |
| | | $\alpha$ | -0.178912 | 0.098636 | |
| | | $\beta_1$ | 0.259776 | 0.056566 | |
| | | $\beta_2$ | -0.822113 | 0.056908 | |
| | | $\beta_3$ | 0.278606 | 0.121763 | |
| | | $\beta_4$ | -0.430309 | 0.134874 | |
| | | $\beta_5$ | -0.337937 | 0.117990 | |
| | | $\delta$ | 0.817191 | 0.194387 | |
| | | $\sigma^2$ | 0.3914 | | |

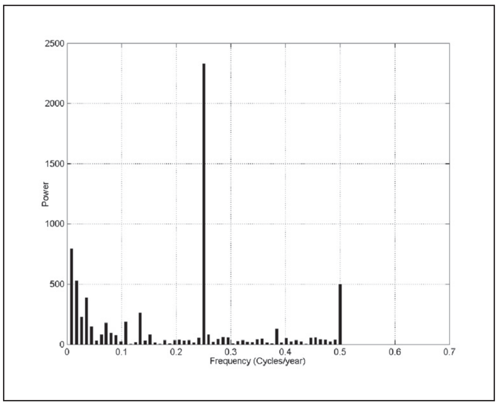


Fig.4. Periodogram plot of standardized series on quarter wise marine fish landings in Karnataka 1960-2000.

significant indicating adequacy of the fitted model. All the parameter estimates of the model (10) for the pre-intervention period were significant and none of the residual autocorrelations for this model was significant. The Box-Ljung statistic was also non-significant indicating suitability of the model for the pre-intervention series. This model could explain 54% of the variations in pre-intervention series. For the intervention model (11), all the parameter estimates were significant except the constant term. Based on the estimate of intervention parameter, the effect of intervention was calculated and it was found that on an average there is an increase of about 88 thousand tonnes in the annual total marine fish landings in Karnataka due to the intervention.

The seasonal *ARIMA* model, by its structure is capable of accounting for the trend and seasonality present in the time series data. Among the two proposed models for analyzing the effects of intervention, the first approach based on seasonal *ARIMA* modeling is more appropriate for the time series data on quarter wise total landings in Kerala than the second one which is based on regression model with *ARMA* type errors. The first intervention model is more efficient than the second intervention model as it could explain an additional 3.11 % of the variations in this time series. Accordingly, the estimate of the effect of intervention made using the first model as 2.26 lakh tonnes per annum is more reliable estimate than the estimate 2.38 lakh tonnes made based on the second approach. Also, the first model is parsimonious having less number of parameters compared to the second model. Since the intervention model using seasonal *ARIMA* did not yield estimate of intervention effect for the time series data on quarter wise total landings in Karnataka, the only feasible solution obtained was through regression model with *ARMA* errors. According to this model, due to the introduction of crafts fitted with outboard engines into the fishery in the state caused an increase of about 88 thousand tonnes per annum.

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