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Forecasting fish production in Bangladesh using ARIMA model

M.E. Haque, M.I. Hossain and K.M.M. Rahman
Department of Agricultural Statistics, Bangladesh Agricultural University, Mymensingh

Abstract

The study tried to find out the best ARIMA model that could be used to make efficient forecast of inland, marine and total fish production in Bangladesh. It also tried to find out the best deterministic type growth model that are commonly used to describe growth pattern and also for forecasting. It appeared from the study that all the time series were second order homogeneous nonstationary. The total and inland production followed a second order integrated moving average process of order one. The process of generating the marine production was different from the other two processes. The second differenced marine production was simply a white noise. The fitness of the models was very satisfactory and forecasts obtained using them had very low standard errors. The forecasted total fish productions in 2000-01 to 2000-05 are 1763, 1867, 1974, 2085 and 2199 thousand tons. The best deterministic type growth models were quadratic for total and inland fish production and cubic for marine production. It also appeared that ARIMA models are the best for short term forecasting compared to the deterministic models.

Keywords: Production, ARIMA, Growth, Forecasting

Introduction

Fisheries, as one of the major sub-sectors of agriculture, have been playing very significant role in increasing nutritional status, employment of the people, foreign exchange earnings etc. It contributes about 4.91 percent to the country's Gross Domestic Product (GDP) and more than 6.28 percent to the foreign exchange earnings (BBS, 2002). Above 1.2 million people have been directly employed in this sub-sector. Another 11 million people indirectly earn their livelihood out of activities related to fisheries (FFYP, 1997-2002).

We get zoological protein (about 80 percent) from fish. So, the importance of the fisheries sector in Bangladesh in terms of nutrition, income, employment and foreign earnings is significant. It has been projected that the population of Bangladesh would reach 137.9 million by the year 2005. If annual per capita fish supply were to reach the level of 14 kg (38 gm/capita/ day), as recommended by the Institute of Nutrition and Food Science, the catch would have to reach 1.9 million tons, an increase of about 14.6 percent over the level of present production (Sarker *et. al.*, 2001). In order to implement the fisheries development program Tk. 5861.80 million has been allocated for the public sector during he Fifth Five Year Plan (1996/97 to 2001/2002). An amount of Tk. 21,847.00 million is expected to be invested by the private entrepreneurs, local and foreign. Export earnings from shrimp, fish and fish products and other aquatic organisms during 2001/2002 were expected to be Tk. 30,045.00 million as against estimated earnings of Tk. 16,000.00 million in 1996/97.

Fish culture systems require a relatively less amount of energy for protein production than any other farming system. Besides, a large number of the country's population depends on fisheries as their source of income. For proper future planning to develop the fisheries sector in order to meet the fish production requirement of the country, it is extremely helpful to know the likely future movement of the production process. For this purpose one or both of the two types of models, usually known as structural regression model and time series model, are often used in practice. The use of structural regression models requires information about the factors affecting the time series. On the other hand, time series analysis, especially Box-Jenkins type ARIMA models, let the data speak for themselves i.e. the future movements of a time series are determined using its own present and past values (Box and Jenkins, 1978). Among the stochastic time series models ARIMA types are very powerful and popular as they can successfully describe the observed data and can make forecast with minimum forecast error. These types of models are very difficult to identify and estimate. They are also expensive, time consuming, and possesses a complex model building mechanism. Another type of time series models, called deterministic growth models, are also very common to use in practice for growth analysis and forecasting, as they are very quick to estimate and less expensive, although less efficient. They are very good in many situations for describing the growth pattern and the future movement of a time series (Pindyck and Rubinfeld, 1991). So far we know no works have been undertaken for forecasting fish production in Bangladesh using ARIMA models. Some works have been done for growth analysis fish production by different authors using deterministic models (Sarker *et. al.*, 2001, Quddus, 2004).

The purpose of this study is to develop appropriate ARIMA models for the time series of inland, marine and total fish production in Bangladesh and to make 5-year forecasts for all the time series with appropriate prediction interval. Another purpose is to compare the forecasting performance of ARIMA and deterministic models for fish production in Bangladesh.

Methodology

Data and Models: The data of annual fish production were collected from the various issues of Statistical Yearbook of Bangladesh Bureau of Statistics (BBS, 1982, 1990, 1999, 2000, 20001) for the period 1966/67 to 1999/2000. The time series' of inland, marine and total fish production were modeled by stochastic autoregressive integrated moving average (ARIMA) process. The most popular Box-Jenkins type ARIMA process of order p, d and q, denoted as ARIMA (p, d, q), may be defined as follows (Box and Jenkins, 1978):

$$\phi_p(B)(\nabla^d Y_t - \mu) = \theta_q(B)\varepsilon_t$$

where Y_t = Fish production at time t

μ = The mean of $\nabla^d Y_t$

$\phi_p(B) = 1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p$

$\theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q$

ϕ_i = The ith autoregressive parameter; i = 1, 2, 3 ...p

θ_i = The ith moving average parameter; i = 1, 2, 3 ...q

p = The autoregressive order

q = The moving average order

d = The times that the series is differenced

∇ = The difference operator

B = The back shift operator

The estimation methodology of the above model consists of three steps viz. identification, estimation of parameters and diagnostic checking. The identification step involves the use of the techniques for determining the values of p, d and q. Here, these values are determined by using autocorrelation and partial autocorrelation functions (ACF and PACF) and Augmented Dickey-Fuller (ADF) test. The second step is to estimate the parameters of the model. Here, the method of maximum likelihood is used for this purpose. The third step is to check whether the chosen model fits the data reasonably well. For this purpose the residuals are examined to find out if they are white noise. To test if the residuals are white noise the ACF of residuals and the Ljung and Box (1978) statistic are used. In case of two or more competing models passing the diagnostic checks the best model is selected using the criteria R^2, RMSE, AIC, BIC, MAE and MAPE,.

Five deterministic type growth models are also considered in this study for comparing the forecasting efficiency of stochastic and deterministic models. These are linear, quadratic, cubic, exponential and compound models. The above mentioned model selection criteria are also used to select the best deterministic model for forecasting purpose. The functional forms and respective formulas of calculating growth rates are given in Table 1.

Table 1. The mathematical forms of the models considered and formulas of growth rates

Model name	Mathematical form	Annual growth rate in %	Meaning of notations
Linear	$Y = a + bt + \varepsilon$	$b / Y \times 100$	Y is the time series considered; t represents time taking integer values starting from 1; ε is the regression residual; a, b, c, and d are the coefficients of the models.
Quadratic	$Y = a + bt + ct^2 + \varepsilon$	$(b + 2ct) / Y \times 100$	
Cubic	$Y = a + bt + ct^2 + dt^3 + \varepsilon$	$(b + 2ct + 3dt^2) / Y \times 100$	
Exponential	$Y = ae^{bt+\varepsilon}$	$b \times 100$	
Compound	$Y = ab^t e^{\varepsilon}$	$(b-1) \times 100$	

Model selection criteria: To identify the best model for a particular time series the following criteria are used.

Coefficient of determination (R^2): The coefficient of determination, proposed by Theil (1961), is the ratio of the regression sum of squares to the total sum of squares i.e. $R^2 = \frac{\text{Regression sum squares}}{\text{Total sum squares}}$. In interpreting R^2, it is generally considered that the more the value of R^2, the better the fit.

Root mean square error (RMSE): The root mean square error is defined as, $\text{RMSE} = \sqrt{\frac{1}{n-k}\sum_{t=1}^{n}\varepsilon_t^2}$, where, n is the sample size and k is the total number of estimable parameters. The model with minimum RMSE is assumed to describe the data series more adequately.

Akaike information criterion (AIC): Akaike's information criterion (AIC), proposed by Akaike (1973), one of the leading statisticians, is defined as $AIC = n\log(MSE) + 2k$, where, n is the sample size, MSE is the mean square error and k is the total number of estimable parameters. Akaike mentioned that the model with minimum AIC is closer to the best possible choice.

Bayesian information criterion (BIC): Schwartz (1978) developed this criterion and it is known as Bayesian Information Criterion (BIC). This is defined as $BIC = n\log(MSE) + k\log n$, where, n is the sample size, MSE is the mean square error and k is the total number of estimable parameters. The model with minimum BIC is assumed to describe the data series more adequately.

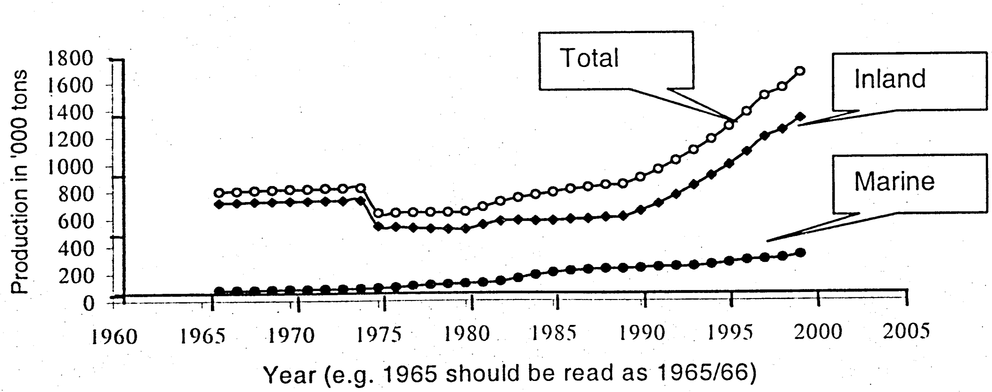
Mean absolute error (MAE): The mean absolute error is defined as $MAE = \frac{1}{n}\sum_{t=1}^{n}|\varepsilon_t|$. The model with minimum MAE is assumed to describe the data series more adequately.

Mean absolute percent prediction error (MAPE): This is defined as $MAPE = \frac{1}{n}\sum_{t=1}^{n}\frac{|\varepsilon_t|}{y_t}\times 100$. The model with minimum MAPE is assumed to describe the data series more adequately.

Results and Discussion

Inland, marine and total fish productions during the period 1966/67 to 1999/2000 are presented in Fig.1. The total fish production in Bangladesh was 802 thousand tons in 1966/67 and it was more or less constant up to 1974/75. In 1975/76 the production declined sharply and became only 640 thousand tons. The pattern of inland fish production during the study period was more or less similar to the total fish production. At the beginning the production was 721 thousand tons and it was more or less constant up to 1974/75. In 1975/76 the production declined sharply and became only 545 thousand tons, afterwards it started increasing steadily up to the year 1990/91. During the period 1991/92 to 1999/2000 the inland fish production increased rapidly and at the end of the study period the production was 1328 thousand tons. Marine fish production was very low during the study period compared to inland fish production.

Fig. 1 Fish production in Bangladesh



At the beginning it was only 81 thousand tons. After then it started increasing gradually and maintained its increasing nature till the end of the study period. It appears from the figure that the growth was slightly higher in the middle (from 1983/84 to 1986/87) of the study period.

Test of stationarity using ACF: Autocorrelation function is a very useful tool to determine whether a time series is stationary or not. Both ACF and PACF are also used to determine the autoregressive and moving average orders of the model. ACF and PACF of our three time series of total, inland and marine fish productions are shown in Fig.2, Fig.3 and Fig.4 respectively. All the graphs show that autocorrelations taper off very slowly indicating that all the series are non-stationary.

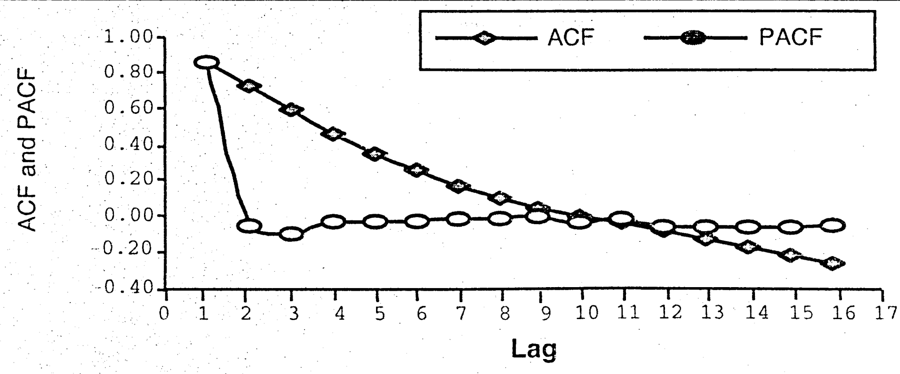


Fig. 2. Undifferened total production

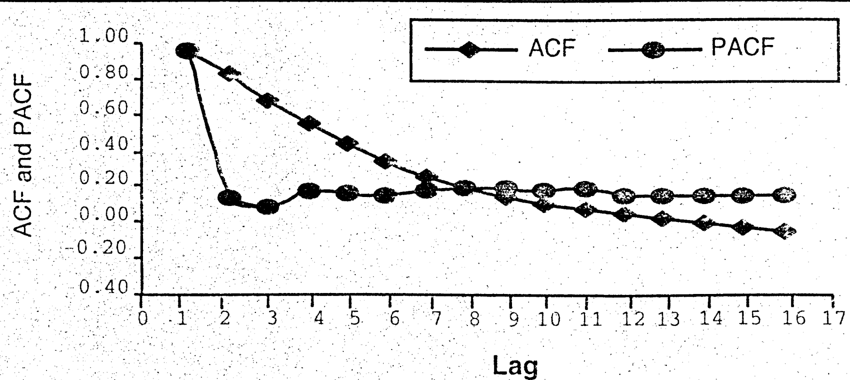


Fig. 3. Undifferenced inland production

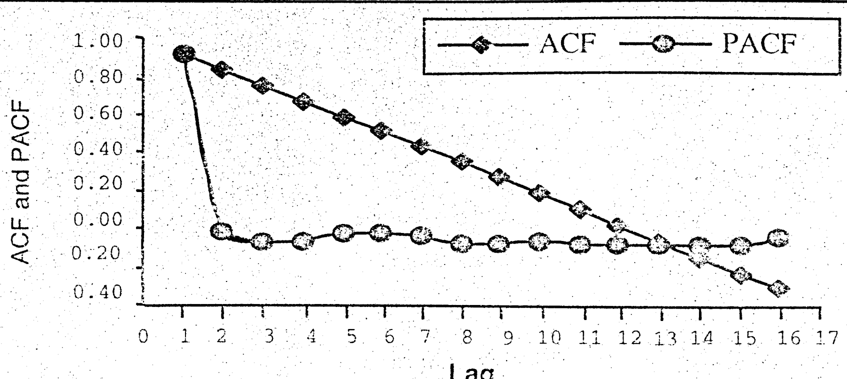


Fig. 4. Undifferenced marine production

Now it is necessary to 1st-difference the time series' and construct autocorrelation functions to see if they are stationary or not. The autocorrelation functions of 1st-differenced time series' of total, inland and marine fish production are shown in Fig. 5, Fig. 6 and Fig. 7 respectively. The 1st-differenced total and inland productions are still nonstationary as the autocorrelations declines slowly. The marine production seems to be stationary, as the autocorrelations declines faster than the autocorrelations of the undifferenced series. Now, we have to examine the stationarity of 2nd-differenced series of total, inland and marine productions.

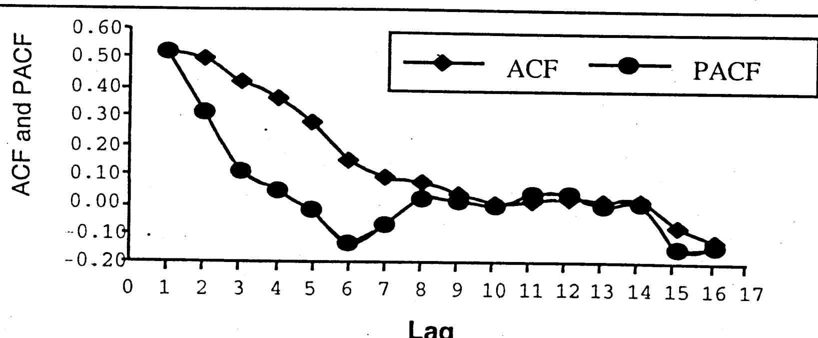


Fig. 5. 1st-differenced total production

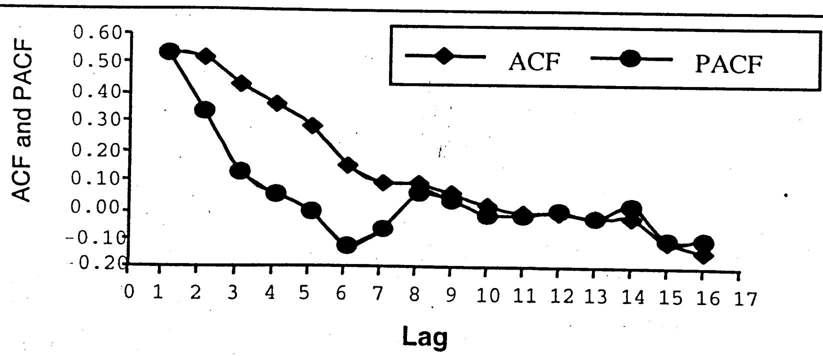


Fig. 6.1st-differenced inland production

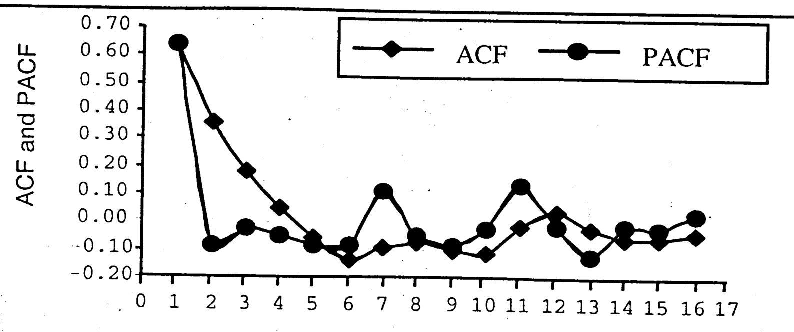


Fig. 7. 1st-differenced marine production

The autocorrelation functions of 2nd-differenced time series' of total, inland and marine fish production are shown in Fig.8, Fig.9 and Fig. 10 respectively. Now it is clearly seen that ACF of all the 2nd-differenced series' decline rapidly and remains small. So, we can say that total and inland productions are stationary of order two and the marine production is stationary of order one or two. Before taking the decision about stationarity of the series we need to carry out the formal ADF test of stationarity.

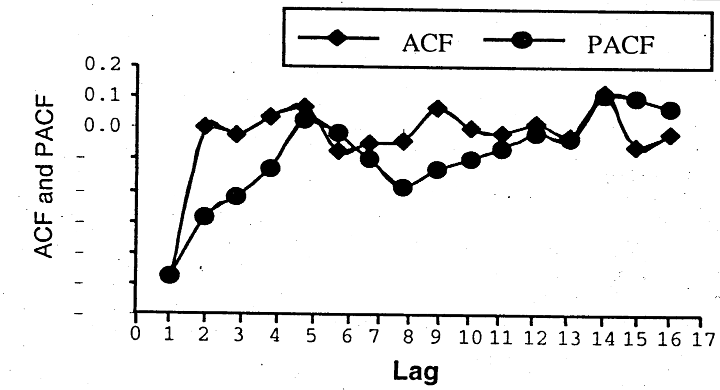


Fig. 8. 2nd-differenced total production

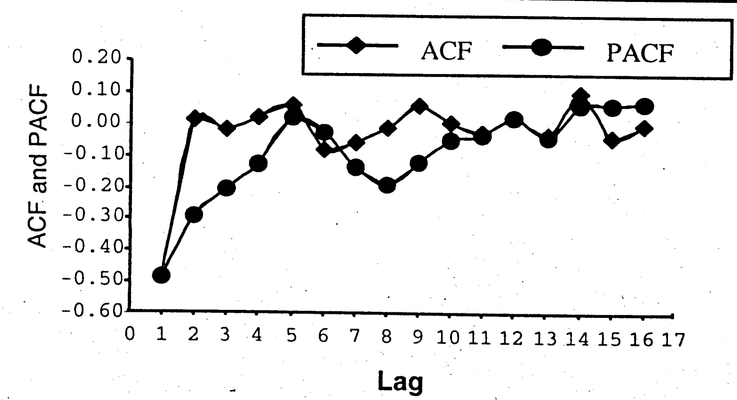


Fig. 9. 2nd-differenced inland production

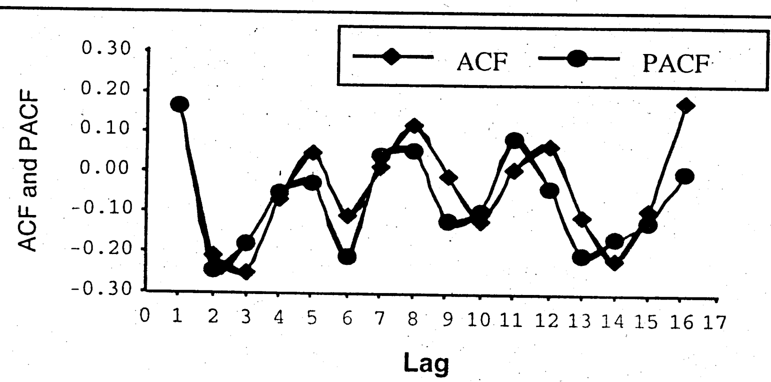


Fig. 10. 2nd-differenced marine production

Test of stationarity using ADF: Apart from the graphical method of using ACF for determining stationarity of a time series, a very popular formal method of determining stationarity is the Augmented Dickey-Fuller test. Here, this test is done for all the time series'. The estimates of necessary parameters and related statistics for the time series of total, inland and marine productions are shown in Table 2.

Table 2. ADF test of stationarity of total, inland and marine fish production

Area	Model	α	β	(ρ-1)	λ	RSS	DF	DW	F	$F_{.05, 34}$
Total	Unrestricted	-65.251	2.900	0.041	0.076	42321.56	28	2.023	6.26	7.06
	S. Error	33.076	1.128	0.046	0.202					
	Restricted	13.494			0.567	61246.65	30	2.309		
	S. Error	8.816			0.159					
Inland	Unrestricted	-65.520	2.867	0.042	0.085	43423.96	28	2.031	5.38	
	S. Error	34.453	0.982	0.049	0.204					
	Restricted	10.390			0.522	60124.13	30	2.295		
	S. Error	8.341			0.162					
Marine	Unrestricted	2.366	0.987	-0.100	0.647	583.98	28	1.325	3.34	
	S. Error	2.088	0.417	0.049	0.144					
	Restricted	2.366			0.774	723.27	30	1.276		
	S. Error	1.314			0.138					

The analysis reveals that the hypothesis of random walk that the underlying process of generating the time series is nonstationary can not be rejected, as the related F statistic is insignificant at 5% level. The total and inland productions are not only nonstationary but they are even involutionary, as the estimate of (ρ-1) is positive. Thus all the undifferenced time series are nonstationary and they must be 1st-differenced to see if the 1st-differenced series' are stationary.

Table 3. ADF test of stationarity of total, inland and marine 1st-differenced fish production

Area	Model	α	β	(ρ-1)	λ	RSS	DF	DW	F	$F_{.05, 33}$
Total	Unrestricted	-42.251	3.421	-0.794	-0.096	41889.83	27	2.032	5.45	7.08
	S. Error	20.362	1.212	0.244	0.188					
	Restricted	4.313			-0.486	58786.12	29	2.261		
	S. Error	8.093			0.165					
Inland	Unrestricted	-42.285	3.055	-0.771	-0.113	42648.69	27	2.044	5.24	
	S. Error	20.587	1.153	0.241	0.186					
	Restricted	3.452			-0.490	59194.32	29	2.272		
	S. Error	8.119			0.163					
Marine	Unrestricted	-0.043	0.214	-0.460	0.487	561.51	27	1.661	4.69	
	S. Error	1.944	0.104	0.155	0.211					
	Restricted	0.680			0.239	756.59	29	1.563		
	S. Error	0.919		0.218						

To carryout the ADF test for the 1st-differenced time series of total, inland and marine fish production the required analysis are shown in Table 3. Again the analysis reveals that all the 1st-differenced time series are nonstationary, as the F-tests are insignificant at 5% level. But none of the 1st-differenced series is found to be involutionary. Again, we will have to difference all the series second time to see if 2nd-differenced series' are stationary. The analysis is shown in Table 4. Now, all the F tests are significant at 5% level. So, we can say that all the time series' are stationary of order two.

Table 4. ADF test of stationarity of total, inland and marine 2nd-differenced fish production

Area	Model	α	β	(ρ-1)	λ	RSS	DF	DW	F	$F_{.05, 32}$
Total	Unrestricted	-6.104	0.618	-1.928	0.304	53263.47	26	2.145	17.50	7.24
	S. Error	20.408	0.961	0.326	0.193					
	Restricted	0.306			-0.680	124970.12	28	2.601		
	S. Error	12.201			0.145					
Inland	Unrestricted	-6.704	0.599	-1.944	0.307	53580.58	26	2.135	17.63	
	S. Error	20.490	0.966	0.327	0.193					
	Restricted	-0.211			-0.683	126241.23	28	2.639		
	S. Error	12.262			0.143					
Marine	Unrestricted	-0.337	0.058	-1.035	0.378	671.64	26	1.938	7.43	
	S. Error	2.306	0.108	0.277	0.225					
	Restricted	0.529			-0.139	1055.584	28			
	S. Error	1.121			0.214					

Thus, from the ACFs and ADF tests we can take the decision that all the time series' are stationary of order two.

Estimated models for total production: From the ACF and PACF of total fish production given in Fig.8 we can say that the autoregressive and moving average orders can not be more than two, as the ACF declines significantly after the 1st lag and the PACF declines significantly after the 2nd lag and there are no significant spikes in both the functions. So, the tentative specifications of the model may be ARIMA (0, 2, 1), ARIMA (0, 2, 2), ARIMA (1, 2, 0), ARIMA (2, 2, 0), ARIMA (1, 2, 1), ARIMA (1, 2, 2), ARIMA (2, 2, 1) and ARIMA (2, 2, 2). All these models are estimated and their diagnostic checks are done using ACFs of residuals and Ljung and Box chi-square test. In addition model selection criteria R^2, RMSE, AIC, BIC, MAE and MAPE are used to select the best model. The value of chi-square with the P-value and the values of model selection criteria are given in Table 5 only for the best model. It is found that the best ARIMA specification for total fish production is ARIMA (0, 2, 1). The model with estimated parameters, standard errors, t and P-values are given below.

$$(\nabla^2 Y_t - 3.458) = (1 - 0.770B)\varepsilon_t$$

SE	(1.854)	(0.126)
t	(1.865)	(6.110)
P-value	(0.072)	(0.000)

According to the model selection criteria the cubic model can be considered as the best deterministic model for total production. But as the linear parameter of this model is insignificant and the fitness of the quadratic model is approximately equivalent to the cubic model and all its coefficients are highly significant the quadratic model is selected as the best deterministic model for total production. It implies that the growth rate of total fish production was not constant during the period. The growth rate function of the model was $(-50.97 + 4.06t)/Y$. The estimated model with necessary statistics is as follows.

$$Y = 980.01 - 50.97t + 2.03t^2$$

SE	(33.731)	(4.443)	(0.123)
t	(29.054)	(-11.470)	(16.446)
P-value	(0.000)	(0.000)	(0.000)

Estimated models for inland production: The ACF and PACF of the 2nd differenced inland production, shown in Fig.9, is similar to those of for the 2nd-differenced total production. So, the same tentative specifications are considered for inland production. It appeared from the analysis that the specification ARIMA(0, 2, 1) is the best. The chi-square test for diagnostic checking for this model is shown in Table 5. The estimated model with necessary statistics are given below.

$$(\nabla^2 Y_t - 2.982) = (1 - 0.7518B)\varepsilon_t$$

SE	(1.992)	(0.127)
t	(1.497)	(5.926)
P-value	(0.145)	(0.000)

According to the model selection criteria the cubic model can be considered as the best deterministic model for inland production. But as the linear parameter of this model is insignificant and the fitness of the quadratic model is approximately equivalent to the cubic model and all its coefficients are highly significant the quadratic model is selected as the best deterministic model for inland production. The estimated model with necessary statistics is as follows.

$$Y = 916.94 - 54.01t + 1.88t^2$$

SE	(36.608)	(4.823)	(0.134)
t	(25.048)	(-11.199)	(14.065)
P-value	(0.000)	(0.000)	(0.000)

Estimated models for marine production: The ACF of 2nd-differenced marine production, shown in Fig.10, reveals that all the autocorrelations are too small and the Ljung and Box test finds all the autocorrelations are insignificant. So, the best model for marine fish production is ARIMA(0, 2, 0). The chi-square test for the residuals and the values of model selection criteria R^2, RMSE, AIC, BIC, MAE and MAPE are given in Table 5. The estimated model with necessary statistics are given below.

$$(\nabla^2 Y_t - 0.75) = \varepsilon_t$$

SE	(0.891)
t	(0.841)
P-value	(0.407)

The best deterministic model for marine fish production is the cubic model given as below.

$$Y = 90.25 - 5.65t + 0.758t - 0.012t^2$$

SE	(8.197)	(1.999)	(0.132)	(0.002)
t	(11.010)	(-2.828)	(5.753)	(-4.710)
P-value	(0.000)	(0.008)	(0.000)	(0.000)

Diagnostic Checking: For diagnostic checking ACF of residuals and Ljung and Box chi-square statistic are widely used in practice. In Table 5 the chi-square statistics are given for all best selected stochastic models with P-values. All the chi-square values are insignificant. It implies that the residuals of the respective time series are white noise implying that the model fitness is acceptable. The estimated values of other model selection criteria for both best selected stochastic and deterministic models are also shown in Table 5.The table reveals that ARIMA models are better than the respective deterministic models.

Table 5. Diagnostic tools and model selection criteria for the best fitted models

Area	Model	R^2	RMSE	AIC	BIC	MAE	MAPE	χ^2 (BL at 16 lag)	P-Value
Total	ARIMA(0,2,1)	0.980	40.71	107.02	106.03	22.13	2.71	5.82	0.990
	Quadratic	0.952	61.74	127.76	126.35	47.29	5.38		
Inland	ARIMA(0,2,1)	0.967	40.96	107.19	106.20	21.51	3.31	3.91	0.990
	Quadratic	0.906	67.01	130.18	128.77	49.17	6.71		
Marine	ARIMA(0,2,0)	0.997	5.03	45.42	45.42	3.58	2.04	13.77	0.616
	Cubic	0.985	10.66	77.88	76.00	6.67	3.28		

Forecasting: Five-year forecasts of total, inland and marine productions are estimated using the best selected models and are given in Table 6, Table 7 and Table 8 respectively. Prediction intervals of forecasts are also given.

Table 6. Total production forecasts

Year	ARIMA(0,2,1)				Quadratic			
	Forecast	LPL	UPL	UPL-LPL	Forecast	LPL	UPL	UPL-LPL
2000-01	1763	1678	1847	169	1677	1534	1821	287
2001-02	1867	1730	2003	273	1770	1623	1918	295
2002-03	1974	1785	2163	378	1867	1715	2020	305
2003-04	2085	1841	2329	488	1968	1810	2126	316
2004-05	2199	1897	2502	605	2073	1909	2237	328

It appeared from the analysis that short term forecasts are more efficient for ARIMA models compared to the deterministic models. ARIMA forecasts are slightly higher than the deterministic forecasts.

Table 7. Inland production forecasts

	ARIMA(0,2,1)				Quadratic			
Year	Forecast	LPL	UPL	UPL-LPL	Forecast	LPL	UPL	UPL-LPL
2000-01	1414	1329	1499	170	1330	1174	1485	311
2001-02	1504	1365	1642	277	1409	1249	1569	320
2002-03	1596	1403	1789	386	1492	1327	1658	331
2003-04	1691	1441	1942	501	1579	1408	1751	343
2004-05	1789	1477	2101	624	1670	1492	1848	356

To meet the minimum fish requirement of the population of Bangladesh the production should exceed 1.9 million ton per year. The forecasted figures show that this requirement will be met by 2005 if the present growth is maintained.

Table 8. Marine production forecasts

Year	ARIMA(0,2,0)				Cubic			
	Forecast	LPL	UPL	UPL-LPL	Forecast	LPL	UPL	UPL-LPL
2000-01	359	348	369	21	321	293	348	55
2001-02	384	361	408	47	325	295	355	60
2002-03	411	371	450	79	328	294	361	67
2003-04	438	378	497	119	330	292	367	75
2004-05	465	384	546	162	331	288	373	85

Table 9 shows the fish production data for the period 2000-01 to 2002-03 as supplied by Fishery Statistical Year Book, 2002-03. It appears from the table that our forecasted values using ARIMA model for the corresponding years are very close to these values. The errors committed are less than 2 percent. This suggests that our model is very much efficient for forecasting fish production for all the three time series viz. total, inland and marine fish production in Bangladesh.

Table 9. Observed fish production in Bangladesh during 2000-01 to 2002-03 in '000 metric ton

Area	Year		
	2000-01	2001-02	2002-03
Total	1781	1890	1998
Inland	1402	1475	1566
Marine	379	415	432

Source: Fishery Statistical Year Book, 2002-03, 20th edition, Department of Fisheries, Dhaka

Conclusion

A time series model accounts for patterns in the past movement of a variable and uses that information to predict its future movements. In a sense a time series model is just a sophisticated model for extrapolation. Time series data and models have become very popular to be intensively used in empirical research and econometricians have recently begun to pay very careful attention to such data. Among the two types of models that are used to describe time series data, we have considered both in this study. For fish production data in Bangladesh ARIMA models are appeared to be more appropriate for short term forecasting compared to deterministic models. The country is appeared to be able to meet the minimum fish requirement (1.9 million tons) by 2005 if the present growth of production can be maintained.

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