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FORECASTING FRESH WATER AND MARINE FISH PRODUCTION IN MALAYSIA USING ARIMA AND ARFIMA MODELS

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ABSTRACT

Malaysia is surrounded by sea, rivers and lakes which provide natural sources of fish for human consumption. Hence, fish is one source of protein supply to the country and fishery is a sub-sector that contribute to the national gross domestic product. Since fish forecasting is crucial in fisheries management for managers and scientists, time series modelling can be one useful tool. Time series modelling have been used in many fields of studies including the fields of fisheries. In a previous research, the ARIMA and ARFIMA models were used to model marine fish production in Malaysia and the ARFIMA model emerged to be a better forecast model. In this study, we consider fitting the ARIMA and ARFIMA to both the marine and freshwater fish production in Malaysia. The process of model fitting was done using the "ITSM 2000, version 7.0" software. The performance of the models were evaluated using the mean absolute error, root mean square error and mean absolute percentage error. It was found in this study that the selection of the best fit model depends on the forecast accuracy measures used.

Keywords: *Fresh water fish, Marine fish, Time series modelling, ARIMA models.*

1. Introduction

Malaysia is surrounded by sea, rivers and lakes which provide natural sources of fish which have been consumed by human since previous era due to their nutritional value (Yusoff, 2015). Therefore, the fisheries sector in Malaysia is an important sub-sector that contribute to the national gross domestic product (GDP) and a source of protein supply to the country (IFMM, 2010). This sector also provides income and employment especially to the rural villagers. According to Fishery Department figures, 2008, Malaysia produces about 1.5 million of fishery products annually of which about 85% are marine capture fish. In 2011, fish consumption which increased to 53.1kg has generated a trade worth of RM6 billion in 2012 and is expected to increase to 61.1kg in 2020 (Yusoff, 2015).

Marine fish are divided into two groups which are pelagic and demersal. Most of the marine catches are pelagic fish with Indian mackerel, round scad, squid, tuna and bream being among the major species caught (Fishery and Aquaculture Country Profiles Malaysia, 2009). According to Information on Fisheries Management in Malaysia, 2010, the marine capture fisheries can be categorized into two main types, namely coastal or inshore fisheries, and deep-sea fisheries. The coastal or inshore fishery, where the fishing vessels operate within 30 nautical miles from the coastline, is an important subsector in socio-economic terms. The coastal fisheries have always been the main focus of fishing activities and there is a general consensus that the coastal fisheries have reached their maximum level of exploitation. The deep-sea fishing vessels operate beyond 30 nautical miles from the shoreline. Basically, commercial gear such as trawls, purse seines and hook-and-line are used. On the other hand, freshwater fish is easy to catch since they can be caught at lakes, reservoirs, rivers, streams and ponds. (Freshwater Fishing, 2017).

Kutty (2016), WWF Living BLUE Planet 2015 reported that some fish species have been declining by close to 75 percent which has given an impact to the fish industry and also protein supply to people due to the high demand. In the last 40 years, fishery resources in Malaysia had declined significantly from 2.56 tonnes per square km in 1971 to only 0.21 tonnes per square km in 2007 (Rajan, 2015). With the increasing affluence and population growth, the increase in local seafood demand will have to come from the aquaculture industry considering the stagnation in marine capture fisheries. Besides, Malaysia is currently a net importer of frozen fish valued at about RM1.1 billion (US$0.31 billion) annually (Ng, 2009). Since there is a concern in the shortfall in supply over demand, it is necessary for us to know the trend of fish production in Malaysia. In addition, knowing the forecast of future fish production in Malaysia will be useful for relevant departments to carry out proper management in the fisheries industry.

Time series models are useful tools used in forecasting and such models have been used in many fields of studies including the field of fisheries (Sembiring et. al., 2010). Bouras (2015) used three individual forecasting models which are the integrated autoregressive moving average (ARIMA), generalize autoregressive conditional heteroscedasticity (GARCH) and Census X-II models to predict the Moroccan coastal fish production. Mini, Kuriakose, & Sathianandan (2015) studied the quarterly fish landing along Northeast coast of India by comparing the following univariate models which are the Holt-Winter's, ARIMA and neural network autoregression (NNAR) models while in Malaysia, Shabri (2016) proposed a new model, MEMD-ARIMA model in his study by considering the monthly fish landing for East Johor. In a previous study, when the ARIMA and fractionally integrated autoregressive moving average (ARFIMA) models were used in forecasting demersal and pelagic marine fish production in Malaysia, the ARFIMA model was found to be the better model (Shitan, Wee, Chin, & Siew, 2008). Since then, fresh data on fish productions in Malaysia has become available. Therefore, in this study, we consider fitting the ARIMA and ARFIMA models for the demersal and pelagic marine fish productions in Malaysia using the new dataset besides as well as modelling the freshwater fish production in Malaysia (Qin et. al., 2014).

2. Methodology

2.1 The dataset

The data used in this study were obtained from the Food and Agriculture Organization of the United Nation (FAO) website for fisheries (Data, 2017). The data consist of 66 observations of the total annual marine fish productions in Malaysia from the year 1950 to 2015. The productions of the total marine fish refer to the quantity of the fish that were caught. The time series plot for the annual pelagic marine fish production in Malaysia from the year 1950 to 2015 is shown in Figure 1.

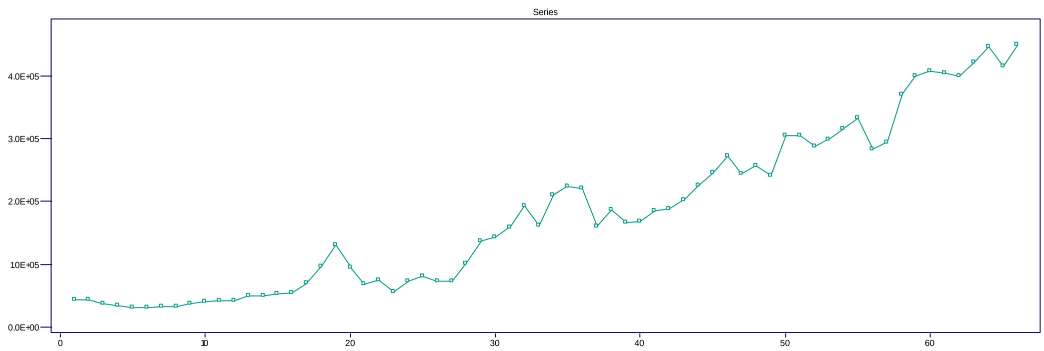

Figure 1: Plot of the annual pelagic marine fish production in Malaysia from year 1950 to 2015.

2.2 Time Series Modelling Procedure

In this study, 54 observations from the year 1950 to 2003 were used to fit the ARIMA and ARFIMA models while the remaining 12 observations from the year 2004 to 2015 were used to check the accuracy of the forecasts obtained from the best fit model. 'ITSM2000' was the software used in the modelling process throughout this study. The accuracy of the forecasts in this study were evaluated using the mean absolute error (MAE), root mean square error (RMSE) and mean absolute percentage error (MAPE) as given in Eq. (1), Eq. (2) and Eq.(3) respectively,

$$\text{MAE} = \frac{1}{n}\left(\sum_{i=1}^{n}|x_i - \hat{x}_i|\right) \tag{1}$$

$$\text{RMSE} = \frac{1}{n}\left(\sum_{i=1}^{n}(x_i - \hat{x}_i)^2\right)^{1/2} \tag{2}$$

$$\text{MAPE} = \frac{1}{n}\left(\sum_{i=1}^{n}\left|\frac{x_i - \hat{x}_i}{x_i}\right|\right) \tag{3}$$

where x_i are the actual observed values and $\hat{x}_i$ are the predicted values while n is the number of predicted values.

The autoregressive moving average, ARMA is a stationary series that combines the autoregressive (AR) and moving average (MA) models. The series y_t is written as $y_t = \mu + \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \cdots + \Phi_p y_{t-p} - \Theta_1 \varepsilon_{t-1} - \Theta_2 \varepsilon_{t-2} - \cdots - \Theta_q \varepsilon_{t-q} + \varepsilon_t$ where μ and Φ_j (j = 1, 2,..., p) are constant terms or parameters to be estimated, y_t is the dependent or current value, y_{t-p} is the $p^{th.}$ order of the lagged dependent or current value, and ε_t is the error term which is assumed independent and identical (iid) with a zero mean and variance σ_ε^2. Θ's are the moving average parameters to be estimated, and ε_{t-q}'s are the error terms (q = *1,2,3,...*) assumed to be independently distributed over time (Lazim, 2013). Since ARIMA is a series when the stationary assumption of the variable is not met, the data series needs to be differenced in order to achieve stationarity. The model is represented as ARIMA (p, d, q) where d is the number of time the variable y_t needs to be differenced in order to achieve stationarity. (Lazim, 2013).

Since the procedures in model fitting are basically the same for the three types of fish productions in Malaysia, we will only discuss the modelling procedure for the pelagic marine fish production in Malaysia in this section. The time series plot for the 54 observations from the year 1950 to 2003 which will be used for model is as shown in Figure 2. As the plot in Figure 2 shows an approximate linear trend, a natural log transformation was performed to stabilize the variance besides differencing the series at lag 1 to remove the trend in order to obtain an approximate stationary series (Peter et. al., 2018). The plot of the transformed series after the mean was subtracted is displayed in Figure 3 while Figure 4 shows the plot of autocorrelation function (ACF) and partial autocorrelation function (PACF) which are useful in identifying the suitable models for the series.

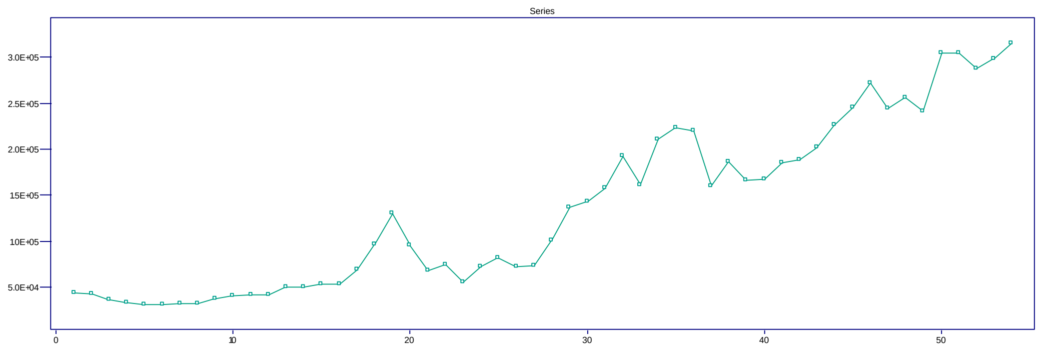

Figure 2: Plot of the annual pelagic marine fish production in Malaysia from year 1950 to 2003.

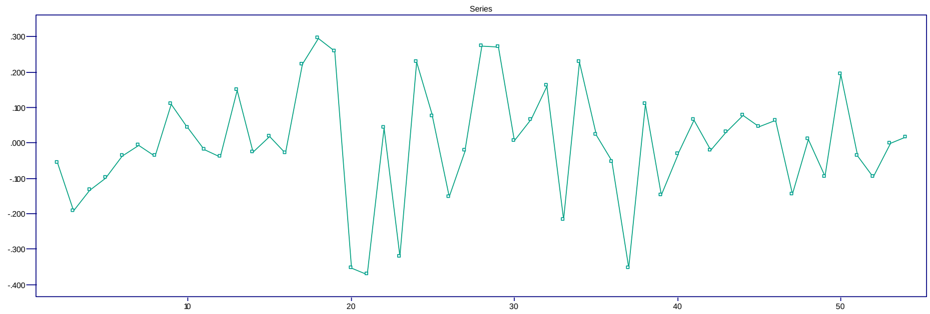

Figure 3: The transformed and differenced time series plot

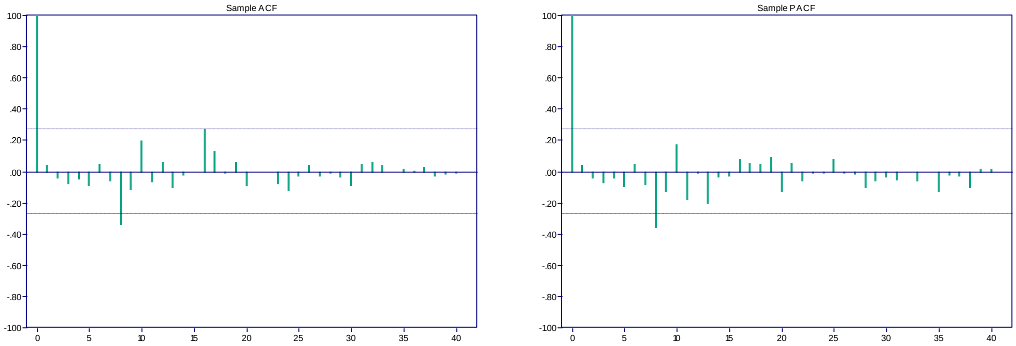

Figure 4: The ACF and PACF of the transformed and differenced time series

To fit the ARIMA model, the ranges of the AR and MA orders were given based on the minimum and maximum values specified using the 'autofit' function in 'ITSM2000'. The best model was chosen based on the smallest AICC statistic (AICC refers to the bias-corrected version of the AIC as cited by Brockwell and Davis (2002)) value which can be defined by Eq.(4)

$$\text{AICC} = -2\, In\, L\left(\phi_p, \theta_q, \frac{S(\phi_p,\theta_q)}{n}\right) + \frac{2(p+q+1)n}{(n-p-q-2)} \tag{4}$$

where $L(\phi, \theta, \sigma^2) = \frac{1}{\sqrt{(2\pi\sigma^2)^n r_0 \dots r_{n-1}}} e\left(-\frac{1}{2\sigma^2}\sum_{j=1}^{n}\frac{(x_j-\hat{x}_j)^2}{r_j-1}\right)$ and $S(\phi,\theta) = \frac{\sum_{j=1}^{n}(x_j-\hat{x}_j)^2}{r_j-1}$. The best fit model will then be used to forecast 12 years ahead from the year 2004 to 2015.

The fractionally integrated autoregressive moving average, ARFIMA is a model that can be expanded which include AR and MA and as well as the fractional difference. ARFIMA (*p*, *d*, *q*) are known to be capable of modelling long-run memory process (Baum, 2013). ARFIMA which has a long memory process with the range of $0 < |d| < 0.5$ is a stationary process with more slowly decreasing autocorrelation function $\rho(k)$ at lag k as $k \to \infty$ which satisfies the property of $(k)\ Ck^{2d-1}$. The model of an ARFIMA process with a time series of order (*p*, *d*, *q*), denoted by ARFIMA (*p*, *d*, *q*) with mean may be written using operator notation $(1-B)^d \Phi(B) X_t = \Theta(B) Z_t$ where $Z_t \sim WN(0, \sigma^2)$. $\Phi(z) = 1 - \Phi_1 z - \dots - \Phi_p z^p$ is satisfying $\Phi(z) \neq 0$ and $\Theta(z) = 1 + \Theta_1 z + \Theta_q z^q$ is satisfying $\Theta(z) \neq 0$. For all z such that $|z| \leq 1$, B is the backward shift operator. The operator $(1-B)^d$ is defined by the binomial expansion of $(1-B)^d = \sum_{i=0}^{\infty} \pi_i B^i$ with $n_0 = 1$ and $\pi_i = \prod \frac{k-1-d}{k}$ for $i = 0,1,2, \dots$ (Brockwell and Davis, 2002).

The initial steps to obtain the transformed series for the ARFIMA model is similar to that of the ARIMA model. However, to fit the ARFIMA model, the value of *d* needs to be specified before running the 'autofit'.

3. RESULTS

3.1 Demersal Marine Fish

The annual forecasts from 2004 to 2015 of the demersal marine fish production in Malaysia using the ARIMA model is the ARIMA (3, 1, 0) as given by Eq.(5) emerged the best model in its class based on the lowest AICC value using the 'autofit' function in ITSM2000. The model is given by

$$X(t) = -0.002205X_{(t-1)} + 0.1123X_{(t-2)} - 0.3581X_{(t-3)} + Z_t \qquad (5)$$

where $\{Z_t\}\sim WN(0, 0.063126)$. The actual productions, forecasts and the 95% forecast boundaries from the year 2004 to 2015 are shown in the Table 1 while their plots are displayed in Figure 5. It is clear that all the actual productions fall within the 95% forecast boundaries and the ARIMA (3, 1, 0) model can forecast the demersal marine fish production for that duration.

Table 1: The annual productions, forecasts and 95% confidence intervals of the demersal marine fish in Malaysia from 2004 to 2015 using the ARIMA (3, 1, 0) model.

Year	Actual Production	Forecast	95% Confidence Interval
2004	14453	12711	(7767.9, 20798)
2005	14199	14782	(7372.8, 29639)
2006	16317	14596	(6025.5, 35356)
2007	17447	15012	(5753.6, 39167)
2008	15817	14578	(5201.9, 40852)
2009	13688	15082	(5099.8, 44602)
2010	14000	15276	(4806.9, 48547)
2011	12155	15908	(4688.7, 53972)
2012	14467	16155	(4444.8, 58716)
2013	15167	16583	(4304.5, 63886)
2014	21913	16807	(4119.9, 68560)
2015	22460	17208	(4003.8, 73961)

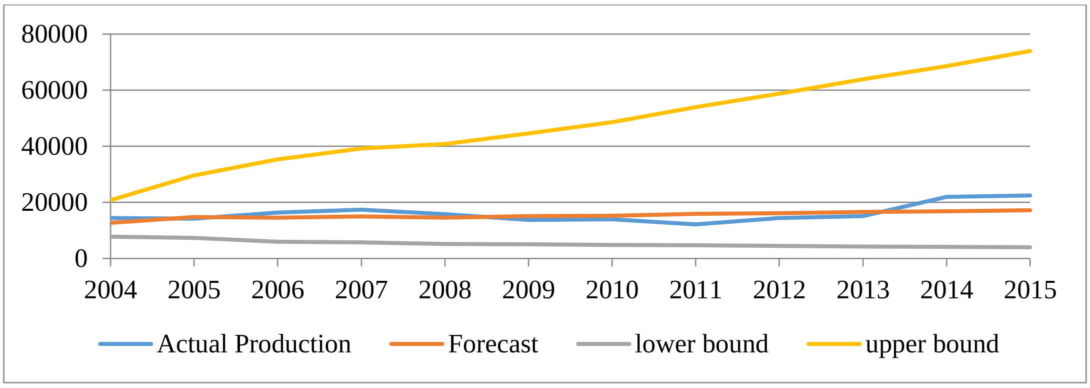

Figure 5: The actual and predicted annual demersal marine fish production using the ARIMA (3, 1, 0) model and together with their 95% forecast boundaries from 2004 to 2015.

When forecasting the annual productions from the year 2004 to 2015 for the demersal marine fish production in Malaysia using the ARFIMA model, the model with the lowest AICC value is the ARFIMA (2, 0.01478, 2) as given by Eq.(6) which is

$$(1-B)^{0.01478}(X_t + 1.685X_{t-1} + 0.7928X_{t-2}) = Z_t + 1.744Z_{t-1} + 0.9376Z_{t-2} \qquad (6)$$

where $\{Z_t\}\sim WN(0, 0.062137)$. The twelve annual productions, forecasts and their 95% confidence intervals are tabulated in Table 2 while their graphs are shown in Figure 6. Similar to the ARIMA models, all the actual production values for the demersal marine fish are within the 95% forecast intervals when forecast using the ARFIMA (2, 0.01478, 2) model.

Table 2: productions, forecasts and 95% confidence intervals of demersal marine fish in Malaysia from 2004 to 2015 using ARFIMA (2, 0.01478, 2) model.

Year	Actual Production	Forecast	95% Confidence Interval
2004	14453	12957	(7602.2, 22083)
2005	14199	12578	(5751.8, 27505)
2006	16317	13496	(5031.5, 36199)
2007	17447	13159	(4275.3, 40502)
2008	15817	13935	(3838.0, 50599)
2009	13688	13857	(3433.9, 55917)
2010	14000	14354	(3103.2, 66395)
2011	12155	14598	(2869.8, 74254)
2012	14467	14827	(2604.9, 84394)
2013	15167	15315	(2454.7, 95546)
2014	21913	15395	(2246.0, 105530)
2015	22460	15986	(2132.3, 119850)

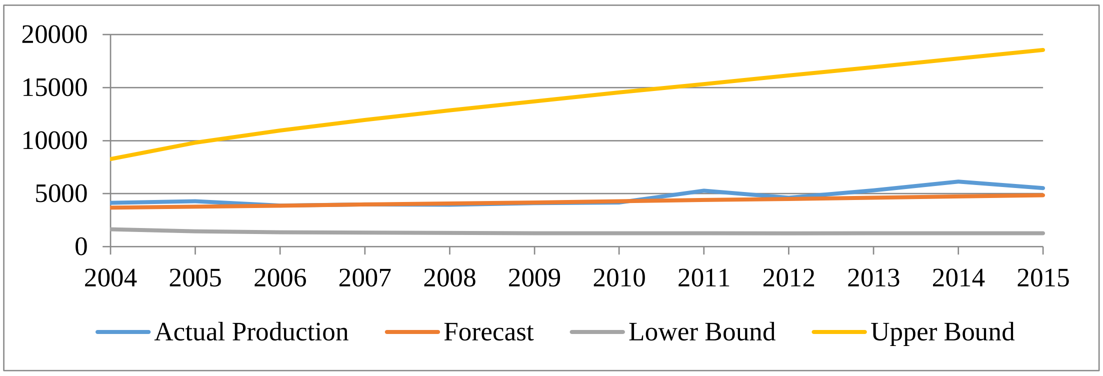

Figure 6: The actual and predicted annual demersal marine fish production using the ARFIMA (2, 0.01478, 2) model and together with their 95% forecast boundaries from 2004 to 2015.

3.2 Pelagic Marine Fish

The best fit ARIMA model used to forecast the pelagic marine fish in Malaysia from the year 2004 to 2015 is the ARIMA (2, 1, 2) as given in Eq.(7).

$$X_t = 1.775X_{t-1} - 0.8954X_{t-2} + Z_t - 1.938Z_{t-1} + 0.9998Z_{t-2} \quad (7)$$

where $\{Z_t\}\sim WN(0, 0.017333)$. The values and plots of the actual values, predicted values together with their 95% forecast intervals are given in the Table 3 and Figure 7 respectively. However, all the actual values of the pelagic fish productions do not fall within the 95% forecast boundaries. In fact, they are below the 95% lower boundaries of the confidence intervals. This result indicates that the ARIMA (2, 1, 2) model is unable to forecast the pelagic marine fish production for the said duration.

Table 3: The annual productions, forecasts and 95% confidence intervals of pelagic marine fish in Malaysia from 2004 to 2015 using ARIMA (2, 1, 2) model.

Year	Actual Production	Forecast	95% Confidence Interval
2004	**332884**	472830	(365290, 612020)
2005	**283189**	501520	(358200, 702200)
2006	**293122**	533810	(366370, 777770)
2007	**370047**	568120	(382520, 843780)
2008	**399626**	602680	(402460, 902490)
2009	**407149**	635700	(423160, 955000)
2010	**404492**	665720	(442520, 1001500)
2011	**398894**	691820	(459340, 1042000)
2012	**421385**	713800	(473010, 1077200)
2013	**447043**	732160	(483100, 1109600)
2014	**415350**	748000	(489240, 1143600)
2015	**448885**	762780	(491300, 1184300)

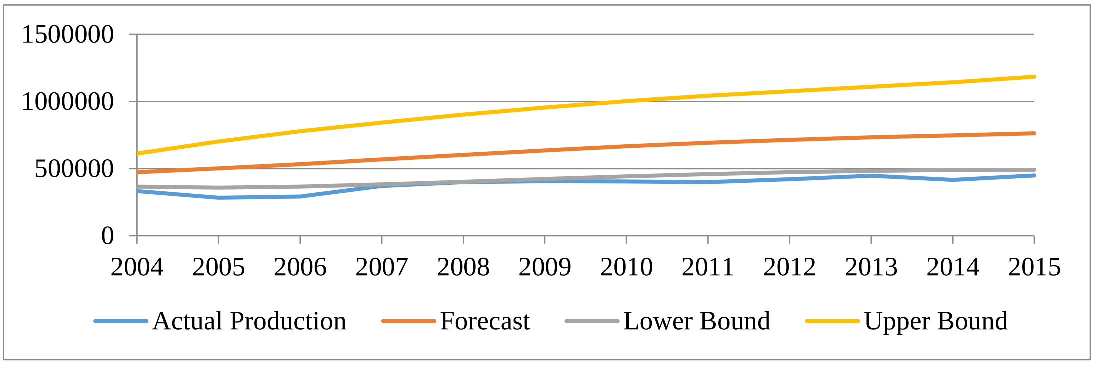

Figure 7: The actual and predicted annual pelagic marine fish production using the ARIMA (2, 1, 2) model and together with their 95% forecast boundaries from 2004 to 2015.

The ARFIMA model with the lowest AICC value that is used to forecast the pelagic marine fish in Malaysia from the year 2004 to 2015 is the AFRIMA (0, –0.02226, 0) given by Eq. (8).

$$(1 - B)^{-0.02226} X_t = Z_t \quad (8)$$

where $\{Z_t\} \sim WN(0, 0.142895)$. The values and plots of the actual values, predicted values together with their 95% forecast intervals are given in the Table 4 and Figure 8 respectively.

Table 4: The annual productions, forecasts and 95% confidence intervals of pelagic marine fish in Malaysia from 2004 to 2015 using Integrated ARFIMA (0, −0.02226, 0) model.

Year	Actual Production	Forecast	95% Confidence Interval
2004	**332884**	465370	(349000, 620540)
2005	**283189**	482490	(322630, 721560)
2006	**293122**	500220	(306680, 815920)
2007	370047	518590	(295690, 909530)
2008	399626	537620	(287670, 1004700)
2009	407149	557330	(281650, 1102900)
2010	404492	577750	(277080, 1204700)
2011	398894	598920	(273620, 1311000)
2012	421385	620850	(271030, 1422200)
2013	447043	643590	(269150, 1538900)
2014	415350	667140	(267880, 1661500)
2015	448885	691560	(267110, 1790500)

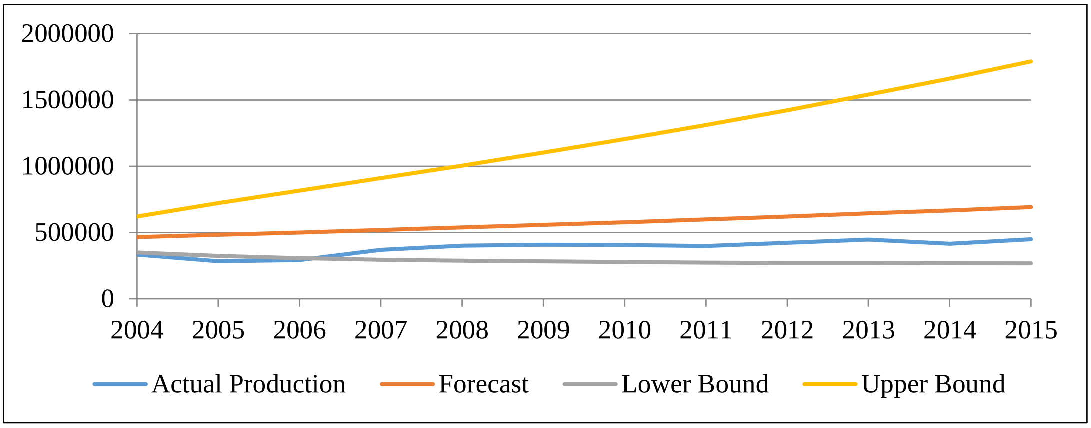

Figure 8: The actual and predicted annual pelagic marine fish production using the ARFIMA (0, –0.02226, 0) model and together with their 95% forecast boundaries from 2004 to 2015.

This result shows that not all the actual values of the pelagic fish productions fall within the 95% forecast boundaries. The actual productions for the years 2004, 2005 and 2006 are below the 95% lower boundaries of the confidence intervals. Again, this indicates the inability of the ARFIMA (0, –0.02226, 0) model in forecasting the pelagic marine fish production in Malaysia.

3.3 Freshwater Fish

The ARIMA model with the lowest AICC value used to forecast the freshwater fish in Malaysia is the ARIMA (1, 1, 1) given by Eq. (9). The model is given by

$$X_t = 0.6439X_{t-1} + Z_t - 1.0000Z_{t-1} \tag{9}$$

where $\{Z_t\}\sim WN(0, 0.138728)$. The actual productions, forecasts and the 95% forecast boundaries from the year 2004 to 2015 are shown in the Table 5 while their plots are displayed in Figure 9. From Figure 9, all the actual productions fall within the 95% forecast boundaries indicating that the ARIMA (1, 1, 1) model can forecast the freshwater fish production for the said duration.

Table 5: The annual productions, forecasts and 95% confidence intervals of freshwater fish in Malaysia from 2004 to 2015 using ARIMA (1, 1, 1) model.

Year	Actual Production	Forecast	95% Confidence Interval
2004	4119	3773.7	(1818.5, 7830.8)
2005	4281	3920.1	(1645.2, 9340.4)
2006	3874	4052.1	(1615.7, 10162)
2007	3981	4175.2	(1631.1, 10687)
2008	3945	4293.4	(1663.4, 11082)
2009	4086	4409.0	(1702.3, 11419)
2010	4150	4523.9	(1744.2, 11734)
2011	5283	4639.3	(1787.6, 12040)
2012	4611	4755.9	(1832.1, 12346)
2013	5296	4874.4	(1877.6, 12654)
2014	6132	4995.1	(1924.0, 12968)
2015	5520	5118.3	(1971.4, 13288)

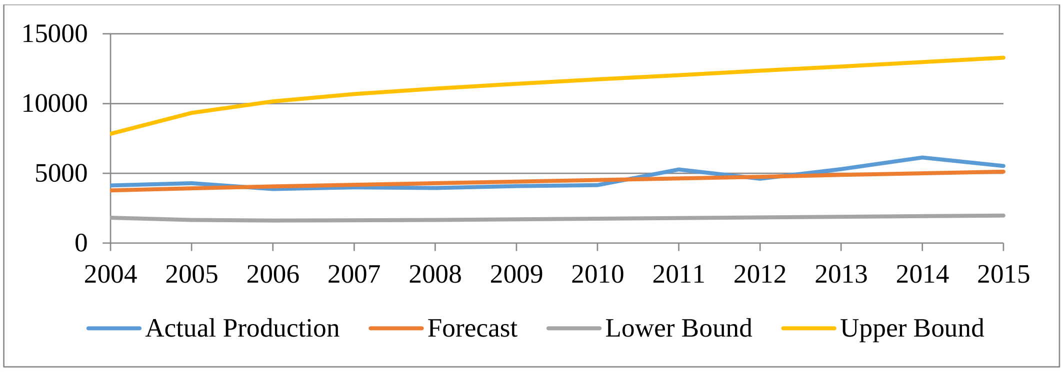

Figure 9: The actual and predicted annual freshwater fish production using the ARIMA (1, 1, 1) model and together with their 95% forecast boundaries from 2004 to 2015.

The ARFIMA model with the lowest AICC values using the 'autofit' function for the freshwater fish production in Malaysia is the ARFIMA (0, −0.3730, 0) as given in Eq. (10).

$$(1-B)^{-0.3730}X_t = Z_t \quad (10)$$

where $\{Z_t\} \sim WN\,(0,\ 0.142895)$. The values and graphs of the actual values, predicted values together with their 95% forecast intervals are given in the Table 6 and Figure 10 respectively. All the actual values are found to be within the 95% confidence intervals of the forecasted values. This result shows that ARFIMA (0, –0.3730, 0) can forecast the freshwater fish production in Malaysia.

Table 6: The annual productions, forecasts and 95% confidence intervals of freshwater fish production in Malaysia from 2004 to 2015 using Integrated ARFIMA (0, −0.3730, 0) model.

Year	Actual Production	Forecast	95% Confidence Interval
2004	4119	3676.1	(1636.4, 8258.1)
2005	4281	3771.8	(1451.0, 9804.4)
2006	3874	3869.9	(1366.9, 10956)
2007	3981	3969.5	(1319.1, 11945)
2008	3945	4070.9	(1289.8, 12849)
2009	4086	4174.3	(1271.5, 13704)
2010	4150	4279.9	(1260.6, 14531)
2011	5283	4387.9	(1255.1, 15340)
2012	4611	4498.3	(1253.6, 16142)
2013	5296	4611.3	(1255.2, 16941)
2014	6132	4727.0	(1259.5, 17741)
2015	5520	4845.4	(1265.9, 18546)

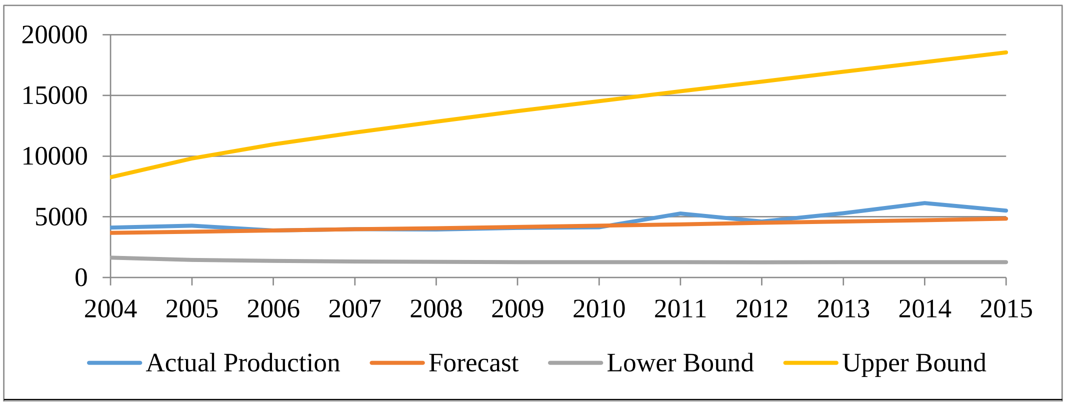

Figure 10: The actual and predicted annual freshwater fish production using the ARFIMA (0, –0.3730, 0) model and together with their 95% forecast boundaries from 2004 to 2015

3.4 COMPARISON OF FORECAST ABILITY FOR THE ARIMA AND ARFIMA MODELS

The comparison of the performance for the ARIMA and ARFIMA models will be presented in this section. However, since both the models are unable to capture the actual values of the pelagic marine fish production in Malaysia as given in Section 3.2, we will only show the comparison of the forecast ability of the models for the demersal marine fish and freshwater fish productions in Malaysia. The MAE, RMSE and MAPE values the demersal marine fish and fresh water fish productions in Malaysia for both the models are tabulated in Tables 7 and 8 respectively. The results show that the ARIMA models perform better when the MAE and RMSE values are used to evaluate the forecast ability of the models. However, when using the MAPE value as the forecast criteria, the ARFIMA models appear to perform better.

Table 7: The MAE, RMSE and MAPE values for the demersal marine fish production in Malaysia

Model	MAE	RMSE	MAPE
ARIMA (3, 1, 0)	**2300.417**	**2738.099**	13.86%
ARFIMA (2, 0.01478, 2)	2381.167	3232.945	**13.45%**

Table 8: The MAE, RMSE and MAPE values for the freshwater fish production in Malaysia

Model	MAE	RMSE	MAPE
ARIMA (1, 1, 1)	**406.0500**	**478.8375**	8.42%
ARFIMA (0, −0.3730, 0)	423.6583	592.1673	**8.25%**

4. Conclusion

In the first part of the study when the ARIMA and ARFIMA models were fitted to the annual marine and freshwater fish productions in Malaysia, the models were only suitable in forecasting the demersal marine fish and freshwater fish productions. Both the models were unable to forecast the production of pelagic marine fish in Malaysia as the actual values were found to be outside the 95% forecast boundaries. Subsequently, it was found that the choice of the forecast accuracy measures is important when it comes to the evaluation of the performance of the models used. As we could see in this study that when the MAE and RMSE values were used for selecting the best model, the ARIMA models emerged as the better models in forecasting the demersal marine fish and freshwater fish productions in Malaysia. However if the MAPE value is selected as the forecast accuracy measurement for model selection then the ARFIMA models can be used as the alternative models in forecasting the demersal marine fish and freshwater fish production in Malaysia. In the previous study, the ARFIMA model was found to be the best model but it is not so in this study. Therefore, from this study, it is clear that when fresh data become available it is important for us to update the models. The models considered in this study were limited to some univariate time series models only. For further study, we suggest the use of other time series models such as the intervention time series and multiple time series.

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