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FORECASTING THE COMMERCIAL CHISAWASAWA(LETHRINOPSSPP.) FISHERY IN LAKE MALAŴI

Matthews Lazaro*

Wilson Wesley Lazaro Jere*

Geoffrey Kanyerere**

Abstract

We developed a time series modelto forecast Lethrinopsspp(locally known as Chisawasawa) for the commercial fishery based on data on Lake Malaŵi fish catch during years from 1976 to 2010. Weconsidered Autoregressive (AR), Moving Average (MA) and Autoregressive Integrated Moving Average (ARIMA) processes to select the appropriate stochastic models for forecasting annual commercial Chisawasawa catch from Lake Malaŵi. Based on ARIMA (p, d, q) and its components autocorrelation function (ACF), partial autocorrelation function (PACF), Normalized Bayesian Information Criterion (NBIC), Box-Ljung Q statistics and residuals estimated, ARI (1, 1) was selected as the best model for forecasting annual commercial Chisawasawa catches. We forecast that the commercial Chisawasawa catch would increase to about 1788 tons in 2020from about 785 in 2010. The confidence intervals for the forecasts include zero, which means that we fail to reject the null hypothesis that the fishery has collapsed. This fishery needs urgent attention. We recommend that these models should be developed for other fisheries in Lake Malaŵi.

Key words: Forecasting, ARIMA, NBIC, *Chisawasawa*,Lake Malaŵi.

* Aquaculture and Fisheries Science Department, Bunda College of Agriculture, P. O. Box 219, Lilongwe, Malaŵi

** Department of Fisheries, Fisheries Research Unit, P. O. Box 47, Monkey-Bay, Malaŵi

1 Introduction

*Lethrinops*spp, locally known as *Chisawasawa*, are among the commercially important species exploited in the inshores of the Lake Malaŵi by artisanal fishermen (Changadeya et al., 2001; NgatungaandSnoeks, 2004; Turner, 1996).Members of the genus *Lethrinops* are among the most successful cichlids in the lake. They occupy the largest habitat, that is, vast stretches of sandy and muddy bottoms, about 95 % of the total available living space for bottom-dwelling fishes (Konings,2007).

In Malaŵi, fisheries data from commercial landings of *Chisawasawa*catches are readily available. These records contain valuable information that can be useful in managing this commercially important fishery. One way is to use the records in determining accurate forecasts of total catches.Since these historical data collected over time are not independent, Box-Jenkins models have been demonstrated to be appropriatein making accurate forecasts. This is because these models are specifically designed for estimating and testing models in the presence of autocorrelated errors (Mendelssohn, 1981). These models are also known as autoregressive integrated moving average (ARIMA) models (Chatfield, 2004). This type of forecasting predicts the values of a continuous variable with a forecasting model based on historical data (Assis et al., 2010).

Time series models have been used to forecast catches in fisheries sectors in different countries. However fish catch forecasting in Malaŵi has been neglected (SADC secretariat, 2009). In this study, we develop and test ARIMA models for forecasting annual commercial *Chisawasawa*catches from Lake Malaŵi.

2 Methodology

The dataused in this paper are univariate time series of total annual commercial *Chisawasawa* fish catch from Malaŵi waters from 1976 to 2010 obtained from Fisheries Research Unit of the Malaŵi'sFisheries Department. The unit of measurement refers to the weight of fish at the time of removal from water in metric tons.A time series plot of the data was made to determine the presence of trend in the series. First order differencing was used to remove the trend in the series. ARIMA models were then fitted to the data. The ARIMA model is as follows:

$$X_t = \sum_{i=1}^{p} \phi_i X_{t-i} + \sum_{j=1}^{q} \theta_j w_{t-j} + w_t$$

where x_t is the original data series or differenced of degree d of the original data at time t,;w_t is the white noise at time t;ϕ_1, ϕ_2, … , ϕ_p are the autoregressive parameters;p is the autoregressive order;θ_1, θ_2, …. ,θ_q are the moving average parameters; and q is the moving average order.Extraction of the lag orders p and$q$ of the time series was done by simultaneous inspection of the autocorrelation function (ACF) and partial autocorrelation function (PACF), respectively. Fitting the model involved the Box-Jenkins three-step procedure as outlined by Chatfield (2004), which involves: identification, estimation and diagnosis. The Box-Ljung Q statistics was used tocheck the adequacy for the residuals.For the purposes of evaluating the adequacy of ARIMA processes, various model fitting statistics like Root Mean Square Error(RMSE), Mean Absolute Percentage Error (MAPE), andBayesian Information Criterion (BIC) were used. Based on Normalized BIC, the principle is that the lower the value the better the model. Fit statistics like MAPE, MAE and RMSE were calculated as given below.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_i - \hat{Y}_i}{Y_i}\right| \qquad MAE = \frac{1}{n}\sum_{i=1}^{n}\left|Y_i - \hat{Y}_i\right| \qquad RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}$$

where $Y_i$and $\hat{Y}_i$ are actual observed values and predicted values, respectively; $n$is number of predicted values.Upon identification of optimum model, forecasts of the catches for ten years were made.All analyses in this study were performed using International Business Management Statistical Package for Social Scientists software (IBM SPSS 20).

3 Results and Discussion

3.1 Model identification

A time series plot for the commercial *Chisawasawa*fishery showed a decreasing trend (Fig. 1). A plot of the autocorrelation function of the differenced series showed an eighth order moving average model while that of the partial autocorrelation function showeda second order autoregressive model (Fig.2).For clear presentation, autocorrelation and partial autocorrelation coefficients (ACF and PACF) of various orders of differenced series of the data were computed and presented in Table 1.Based on these coefficients, various tentative models were identified and the models together with their corresponding fit statistics are given in Table 2. The ARI (1, 1) model with the lowest Normal BIC value of 13.168 was selected.

3.2 Model estimation

Having obtained suggested model, the estimates for the parameters were found as given in Table 3. The coefficients parameters of the model were found to be statistically significant; a requirement for forecasting models.

3.3 Diagnostic checks

Diagnostic checks on the proposed best model for commercial *Chisawasawa* involved checking the residuals of the model to see if they contained any systematic structure which still could be removed to improve the selected ARIMA model. Inthis study diagnostic checking was achieved by examining the autocorrelations and partial autocorrelations of the residuals of various orders. To accomplish this, various autocorrelations up to 24 lags for commercial *Chisawasawa*were computed and plotted as indicated in Figure 3. As the plots of ACF and PACF residuals indicate, none of autocorrelations was significantly different from zero. This proved that the selected ARIMA model was appropriate models for forecasting *Chisawasawa*fish catch from LakeMalaŵi. From the plots it is clear that the autocorrelation coefficients of the residuals are within 95% confidence interval. This supported that the selected model was optimum for commercial *Chisawasawa* catch forecasting. The fitted ARIMA modelis:

$$x_t = 2371.829 - 0.905x_{t-1} + w_t$$

3.4 Forecasting

Forecasts for commercial *Chisawasawa* were made for the period of ten yearsusing the fitted model. In order to assess the ability of the model in forecasting, the 33 observations were plotted with predicted values for the purposes of checking the accuracy of post sample forecasting. For the parsimonious representation, only the last 10 observations have been compared with the forecasted values as shown in Tables 4. However, all observations and forecasted values together with their 95 % confidence interval are given in Figures 4 (Shitan et al.2008). In this study, the forecasted and actual values were close, meaning the forecasting error was low which is good for a model. Czerwinski et al. (2007) pointed out that a good model has a low forecasting error, therefore when the distance between the forecasted and actual values are low then the model has a good forecasting power.

The mean annual catches from commercial fishery will increase until 2020. However, the 95 %

confidence interval for this fisheryincludes a 0, which means that we cannot reject the null hypothesis that the mean catches have reached their zero point. This shows thatthe fishery has completely collapsed. Although the *Chisawasawa* fishery appears to be the most successful in the Lake, these results have shown that the Department of Fisheries of the Malaŵi Government need to put in place management options for sustainable harvesting of this commercially important fish group.

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Table 1.ACF and PACF coefficients for first order differenced data of commercial *Chisawasawa* fishery.

			Box-Ljung Statistic				
Lag	ACF	SE	Value	df	Sig.	PACF	SE
1	-0.406	0.164	6.111	1	0.013	-0.406	0.171
2	-0.185	0.162	7.420	2	0.024	-0.419	0.171
3	0.174	0.159	8.615	3	0.035	-0.149	0.171
4	-0.104	0.157	9.053	4	0.060	-0.217	0.171
5	0.097	0.154	9.449	5	0.092	-0.011	0.171
6	0.053	0.151	9.572	6	0.144	0.093	0.171
7	-0.326	0.149	14.383	7	0.045	-0.289	0.171
8	0.342	0.146	19.874	8	0.011	0.090	0.171
9	-0.087	0.143	20.244	9	0.016	-0.055	0.171
10	-0.010	0.140	20.249	10	0.027	0.148	0.171
11	-0.051	0.137	20.390	11	0.040	-0.109	0.171
12	-0.084	0.134	20.780	12	0.054	-0.138	0.171
13	0.049	0.131	20.918	13	0.075	-0.217	0.171
14	0.030	0.128	20.973	14	0.102	-0.283	0.171
15	-0.090	0.125	21.498	15	0.122	-0.199	0.171
16	0.199	0.121	24.196	16	0.085	0.008	0.171

Table 2.Fit statistics for various competing ARIMA models for the commercial *Chisawasawa*fishery.

ARIMA (p, d, q)	RMSE	MAPE	MaxPE	MAE	MaxAE	NBIC
ARIMA (1, 1, 1)	626.01	30.06	188.28	456.67	1837.42	13.18
ARIMA (1 ,1, 0)	653.52	31.04	196.29	483.15	1813.35	**13.17**
ARIMA (0, 1, 1)	898.03	66.99	545.09	766.65	1868.02	13.80
ARIMA (0, 1, 3)	769.56	46.24	326.15	582.73	1851.96	13.70s

Table 3. Parameter estimates for ARI (1, 1) model.

	Estimate	SE	T-value	P-value
constant	2371.829	877.300	2.704	0.011
AR 1	0.905	0.076	11.895	0.000

Table 4. Forecasts of commercial *Chisawasawa*catch (in tons) together with 95 % confidence interval

Year	Actual Catch	Predicted catch	95 % Confidence Interval
2001	1351	1445	(249,2641)
2002	764	1448	(252,2644)
2003	1237	917	(-279,2113)
2004	1032	1345	(149,2541)
2005	525	1159	(-37,2355)
2006	556	700	(-495,1896)
2007	246	729	(-467,1925)
2008	576	448	(-748,1644)
2009	468	746	(-450,1942)
2010	785	649	(-547,1845)
2011	-	936	(-260,2132)
2012	-	1073	(-541,2685)
2013	-	1196	(-691,3083)
2014	-	1308	(-777,3392)
2015	-	1409	(-824,3643)

2016	-	1501	(-848,3849)
2017	-	1583	(-855,4022)
2018	-	1658	(-852,4168)
2019	-	1726	(-841,4293)
2020	-	1788	(-825,4400)

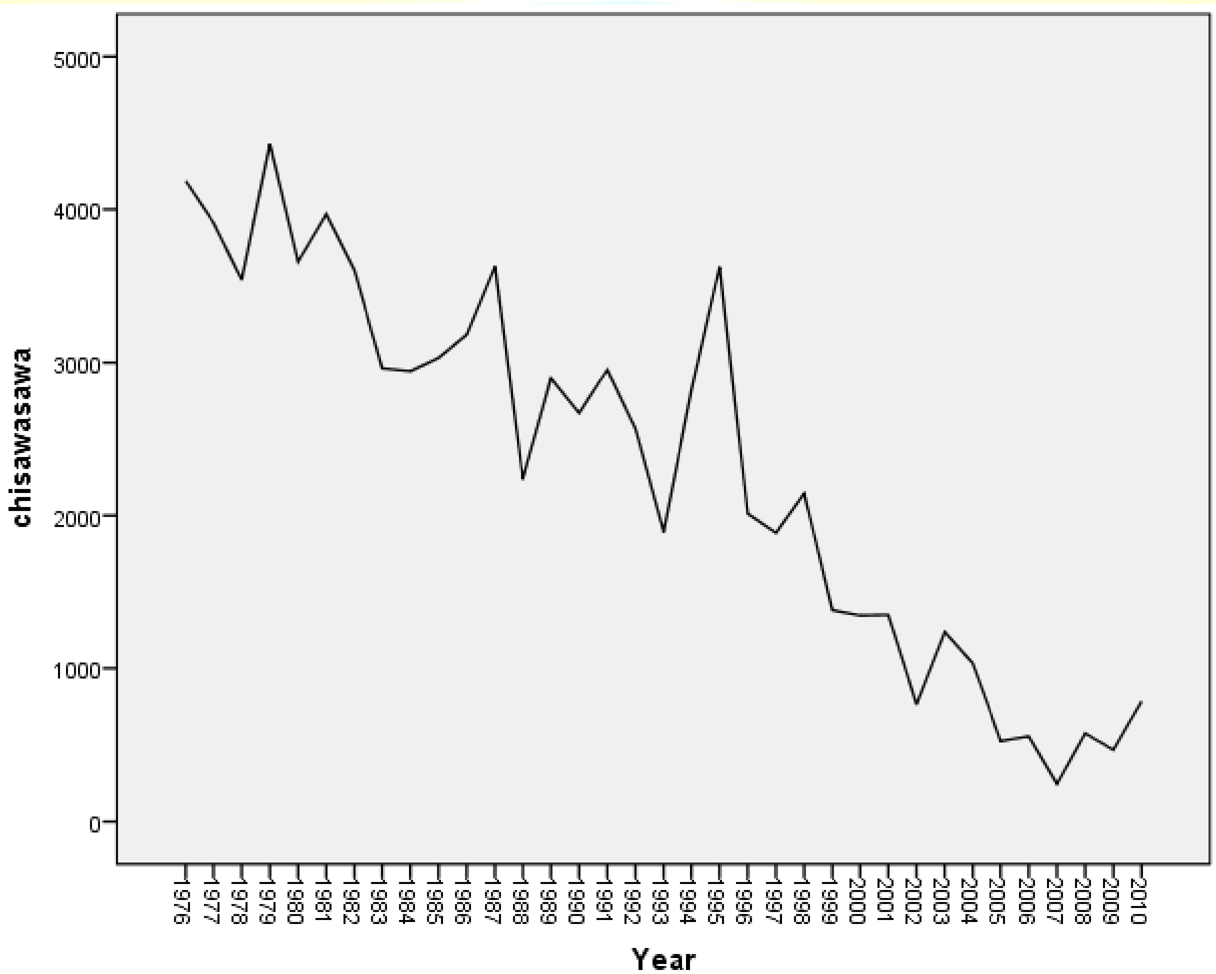

Figure 1. Catch of commercial chisawasawa from Lake Malawi for period 1976 to 2010.

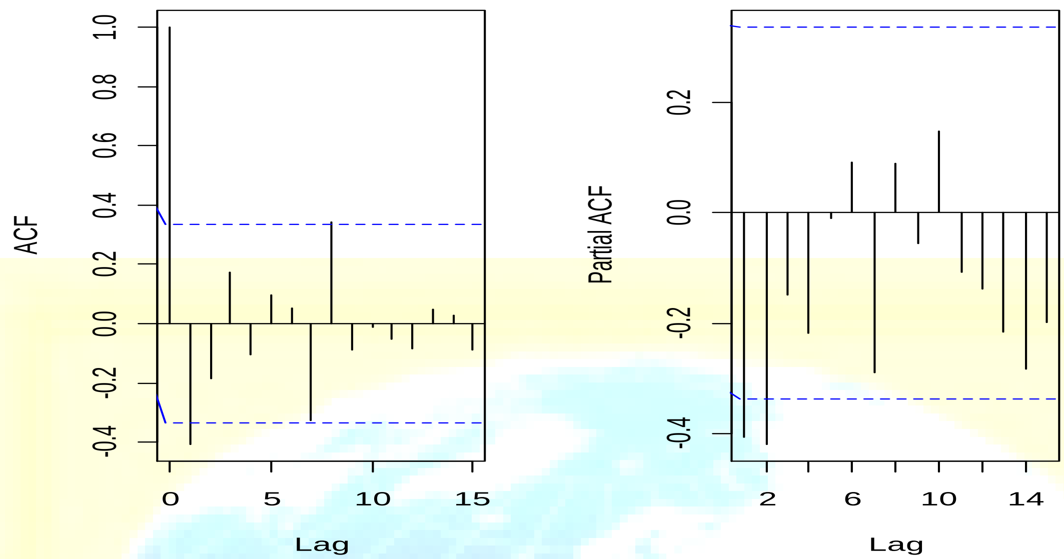

Figure 2.ACF and PACF of first order differenced commercial chisawasawa data

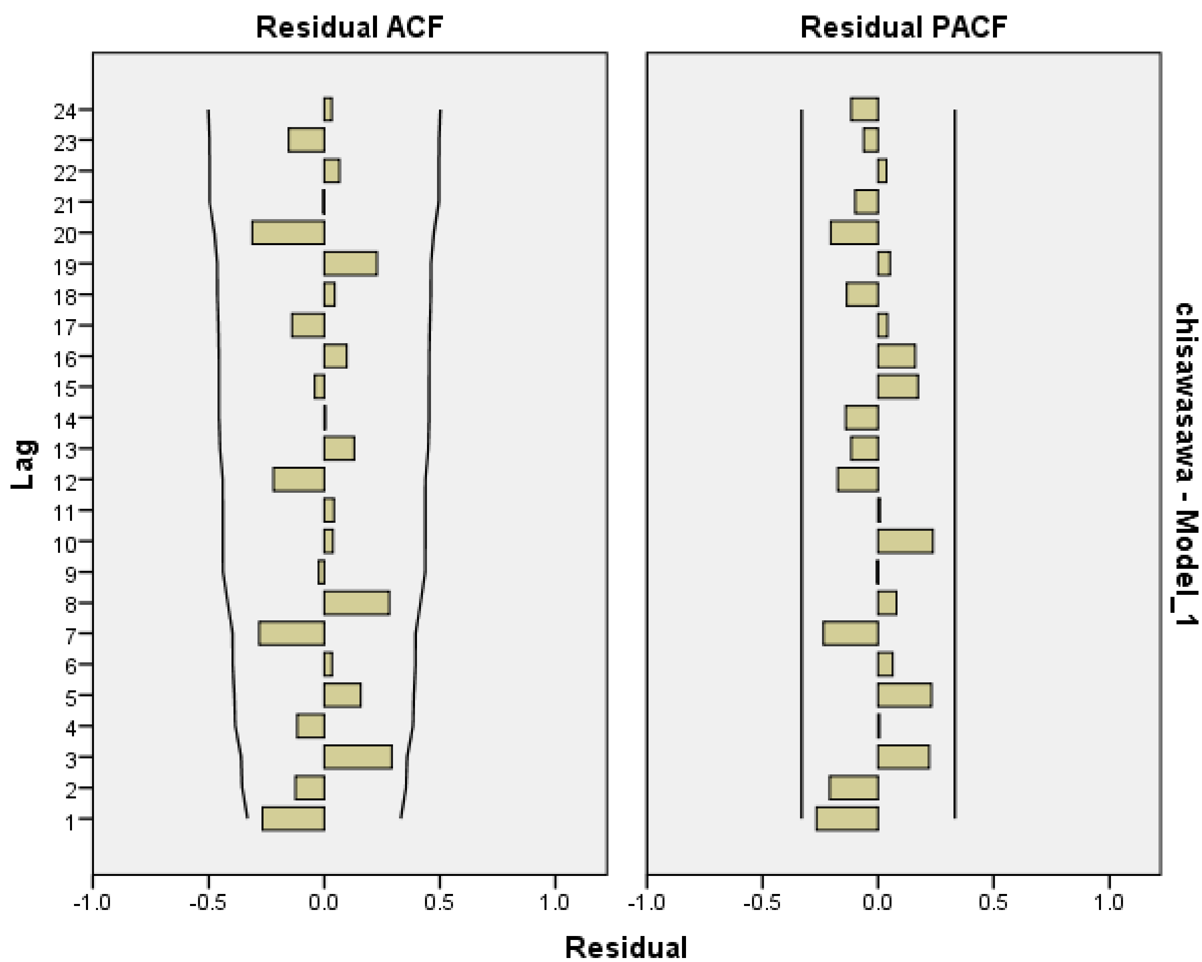

Figure 3. ACF and PACF residuals for commercial chisawasawa

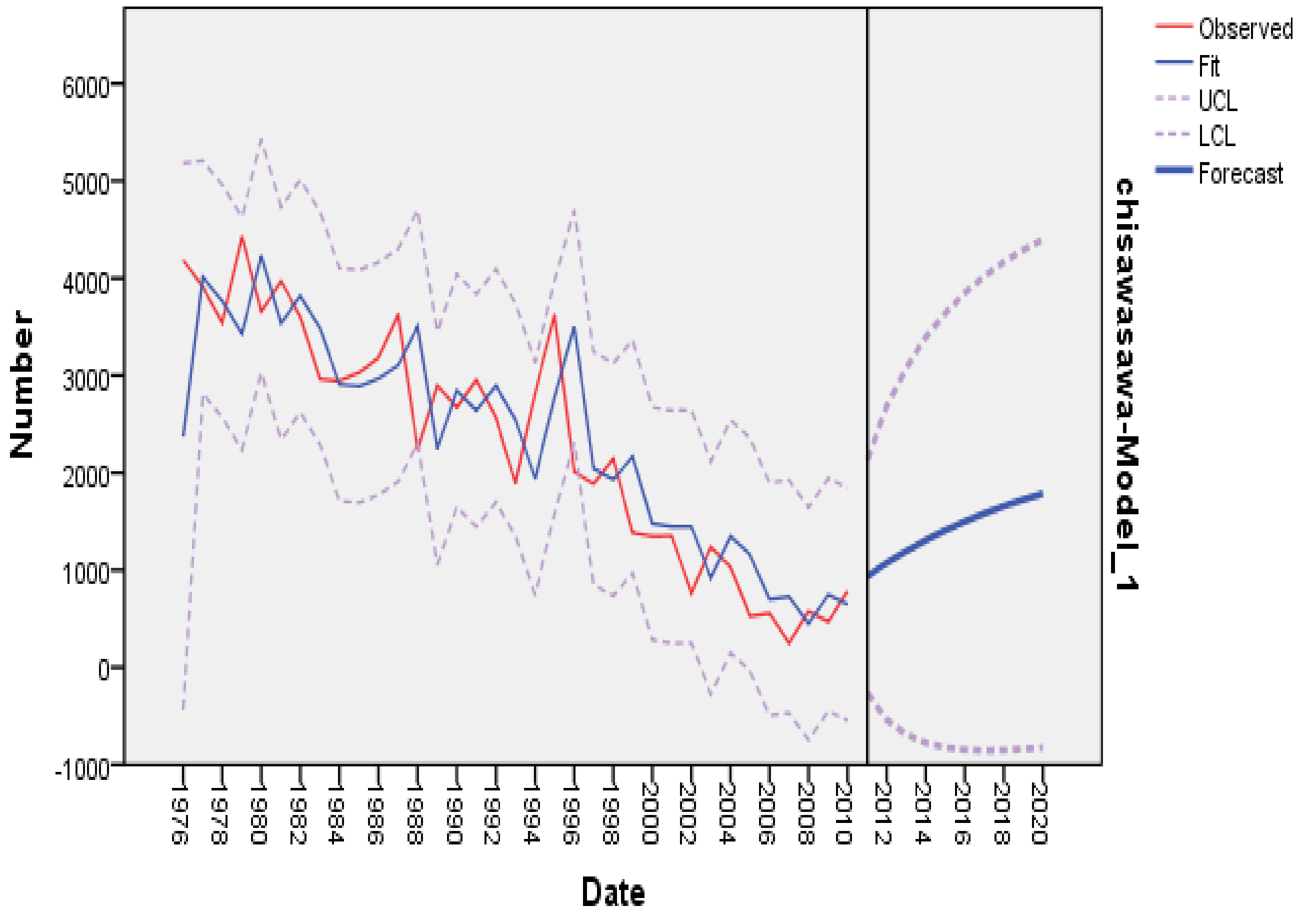

Figure 4.Actual and forecasted commercial chisawasawa catch from Lake Malawi