

Application Of Forecasting In Determining Efficiency Of Fisheries Management Strategies Of Artisanal *Labeo mesops* Fishery Of Lake Malawi

Mulumpwa, M, Jere, W.W.L, Mtethiwa, A.H.N, Kakota, T, Kang'ombe, J.

Abstract: The *Labeo mesops* together with its family members, the cyprinids have been reported declining in population. The exploitation levels are not matching the species carrying capacity for the populations to rejuvenate. As such several management strategies including restocking were put in place to restore the fishery. There is a need to quantify the efficiency of these strategies in managing and restoring the species fishery. The study aimed at modelling and forecasting *Labeo mesops* (Ntchira), yield from artisanal fishery on Lake Malawi in Mangochi district based on time series data on catches of the species during the years of 1976 to 2012 collected from the Department of Fisheries in Malawi. The study considered Autoregressive Integrated Moving Average (ARIMA) processes to select an appropriate stochastic model for forecasting the species yield. The appropriate model was chosen based on ARIMA (p, d, q). The Autocorrelation function (ACF), Partial autocorrelation (PACF), Akaike Information Criteria (AIC), Box-Ljung statistics, correlogram and distribution of residual errors were estimated. The selected model was ARIMA (0, 1, 1) for forecasting the artisanal landings of *Labeo mesops* from Lake Malawi in Mangochi District from the year 2013 to 2022. The forecast showed that the species could have already collapsed since the forecast were in negatives implying that the stock of *Labeo mesops* may no longer be available by the year 2022 in the landings holding other factors constant. The study showed that the current fisheries management strategies are failing to manage the artisanal *Labeo mesops* fishery in the region as it is succumbing to the theory of 'Tragedy of Commons'.

Key words: forecasting, modelling, ARIMA, landings, *Labeo mesops*, tragedy of commons

1. Introduction

Most of conventional fisheries management are based on management of the fishery resource through biological or bio-economic models, however, fisheries management is more of fishers management (Berkes *et al.* 2001). This is the reason of late fisheries managers have opted to incorporate participation of fishing communities in the management of the fishery resources in a way of co-management (Njaya 1998, Donda 2000, Berkes *et al.* 2001). Malawi is currently employing co-management to the management of its fisheries resources (Njaya 1998, Donda 2000). Other fisheries and natural resource managers worldwide are advocating for ecosystem based management system which includes management of the fishing communities (O'Leary 2008). This comes amid understanding that it is ineffective to manage the fishery resources sole without inclusion of other stakeholder to manage the factors contributing to dwindling of the fish landings within their jurisdiction. For instance, the forestry and crop production sectors should ensure that deforestation and poor farming practices are controlled to avoid increased soil erosion leading to increased siltation of water bodies hence causing habitat destruction.

Fisheries management in Malawi among other things centers on managing the fishers' entry into the fishery resources and the type of gear they use. In line with managing fishing communities, the major problem brings about a useful theory in fisheries management called "tragedy of the commons". This theory is about the divergence between individual and collective rationality (Berkes *et al.* 2001). Resources that start out abundant and freely available to all tend to become ecologically scarce (Berkes *et al.* 2001), a problem which is exacerbated by the common property regime in the management of artisanal fisheries in Malawi (Maguza-Tembo, 2002). The theory states that in common access fisheries regime the fishers will increase in both numbers and their fishing effort exceeding the carrying capacity of the fishery resources leading to overexploitation. The commons dilemma in fisheries comes into play where fishers take the fishery resource as a fugitive, and that the fish they do not catch as an individual today may be caught by someone else tomorrow (Berkes *et al.* 2001). It is difficult to see a fisher's incentive to conserve the resource, as opposed to catching as much as possible, as soon as possible; especially in a case of Malawi where the demand for fish on the market is high (Government of Malawi 2012). However, since each fisher operates with the same rationality, the users of the fishery commons are caught in an inevitable process that leads to the destruction of the very resource on which they all depend. Because each user ignores the costs imposed on others, individually rational decisions accumulate to result in a socially irrational outcome (Berkes *et al.* 2001). This scenario has led to over exploitation of some of the individual species fishery from water bodies in Malawi as the case with *Labeo mesops*, locally known as Ntchila. The Department of Fisheries and other stakeholders in Malawi are employing different strategies from fisheries policy document to manage the commons. Several routine activities have been done including projects aimed at restocking *Labeo mesops* such as 'Aquaculture Development of Indigenous Species in Malawi' funded by

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Japan International Cooperation Agency (JICA) (Msiska, 1986, Morioka *et al.*, 2002), among others for this course. However, it is important to quantify how much success the Department of Fisheries in Malawi and other stakeholders have achieved to manage the commons and the fishery of *Labeo mesops* at large in Lake Malawi in Mangochi District. The *Labeo mesops* together with its family members, the cyprinids have been reported declining in population since 1960s (Walker, 1976). This study will use landings data of *Labeo mesops* fishery in Lake Malawi in Mangochi District to forecast using ARIMA process the species landings and determine if the management system in place will work in the future for the fishery. This will equip the fisheries managers with critical information to incite policy modification or formulation to efficiently manage the fishery resource (Stergiou and Christou, 1996). Forecasting plays a very important role in management as it enables prudent planning leading to informed decision making (Craine, 2005). Forecasting precedes planning which, in turn, precedes decision making (Makridakis *et al.*, 1983). In Malawi, literature shows that very little has been done to use forecasting methods in fisheries. Singini *et al.* (2012 and 2013) did forecast studies on *Haplochromine* species (kambuzi) and *Oreochromis* species (chambo) production of Lake Malawi and Lake Malombe respectively and, Lazaro and Jere, (2013) on commercial chambo fishery in Lake Malawi. Their results indicated that *Haplochromine* species and commercial chambo fisheries would increase through the year 2021 in Lake Malawi while *Oreochromis* species fishery of Lake Malombe would decline through the same period. There is a big gap in as far as forecasting in fisheries in Malawi which this study seeks to bridge.

2. Methodology

The study was carried out on only the artisanal fishery on the following minor strata 2.1, 2.2, 2.3, 2.4, 2.5, 2.6 and 3.1 on Lake Malawi in Mangochi District. The Department of Fisheries provided the time series fish landings data used in this study. The fish landings in this study were wet weight measurements in kilograms and were later converted to tonnage annually.

2.1 Forecasting using ARIMA model

The data was assumed to be non-seasonal on annual basis as the *Labeo mesops* landings are not seasonal except on monthly basis, ARIMA fitted the data very well. The ARIMA process was employed as described by Box and Jenkins (1970) through identification, selection of candidate ARIMA model, diagnostic checks and forecasting. The fish landings data for *Labeo mesops* (Ntchila) in this study were subjected to stationarity test by using two methods namely graphical analysis method and the Dickey – Fuller test. The data was found stationary hence was differenced since the ARIMA model works where the data is stationary. The differenced series was also subjected to stationarity test as was the case with the original series to prove if the transformation really made it stationary. The differenced data was found stationary hence was ready for modelling with ARIMA process.

2.2 Selecting a candidate ARIMA model

Model identification was done by generating correlogram and partial correlogram from the stationary differenced data

in order to identify an appropriate model for the fish landings. This was aimed at finding the most appropriate values of p and q for an ARIMA (p, d, q) model. Where the partial autocorrelation function (PACF) had a cut-off at p while the autocorrelation function (ACF) tailed off, it gave an autoregressive (AR) of order p while where the ACF had a non-zero lag at q , it gave a moving-average (MA) of order q . However, where there was non-zero lag(s) on both ACF and PACF, the autoregressive integrated moving-average (ARIMA) p, d, q was employed. Where d is number of times the data has been differenced to remove the noise within it, in this case; one (1) as the original data was differenced once to make it stationary. An autoregressive model (AR) of a time series $\{X_t\}$ is a regression model of that time series on its previous history (Craine, 2005). Autoregressive process of order (p) was found by using the following model;

$$X_t = \sum_{j=1}^p \phi_{t-j} + \varepsilon_t \quad (1)$$

A moving average (MA) model of a time series was aimed at averaging out previous error steps of a time series $\{X_t\}$ to attempt to smooth the process or make the time series stationary. Moving Average process of order (q) was found by using the following model;

$$X_t = \sum_{j=1}^q \theta_j \varepsilon_{t-j} + \varepsilon_t \quad (2)$$

The combination of linear autoregressive and moving average properties results into the autoregressive moving average (ARMA): ARMA of order (p, q) was denoted by,

$$X_t = \sum_{i=1}^p \phi_i X_{t-i} + \sum_{j=1}^q \theta_j \varepsilon_{t-j} + \varepsilon_t \quad (3)$$

The general form of ARIMA model of order (p, d, q) was denoted by;

$$x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + \dots + \phi_p x_{t-p} + w_t + \theta_1 w_{t-1} + \theta_2 w_{t-2} + \dots + \theta_q w_{t-q} \quad (4)$$

Where: x_t is the original data series or differenced to degree d of the original data at time t ; w_t is the white noise at time t ; $\phi_1, \phi_2, \dots, \phi_p$ are the autoregressive parameters; p is the autoregressive order; $\theta_1, \theta_2, \dots, \theta_q$ are the moving average parameters; q is the moving average order.

2.3 Model parameter estimation

After the model was identified as AR, MA, ARMA or ARIMA then it was fitted by estimating its best possible parameters. The Akaike Information Criteria (AIC) was used to identify the best fitting model as described by Satya *et al.* (2007).

2.4 Forecasting

After the parameters of the selected ARIMA (p, d, q) model was estimated and fitted, the model was used to forecast the future landings. The fitted ARIMA model was then used to make predictions of the future (next ten (10) years) of *Labeo mesops* fish landings.

2.5 Diagnostic checks

The made forecasts were subjected to various diagnostic tests to quantify the extent to which the forecast could be trusted by plotting of autocorrelation of the residuals and carrying out the Ljung-Box test. A good ARIMA model should make forecasts with forecast errors with a mean of zero, constant variance, no significant correlations between successive forecast errors and normally distributed. The process was restarted through the four steps in the ARIMA modelling process once the selected model was found to

have failed the diagnostic checks until the selected model passed the tests.

3. Results and discussion

3.1 Identifications of models

The plotted original series was visibly not stationary as shown in Figure 1. The original series was fluctuating so much over the years hence did not have a constant variance.

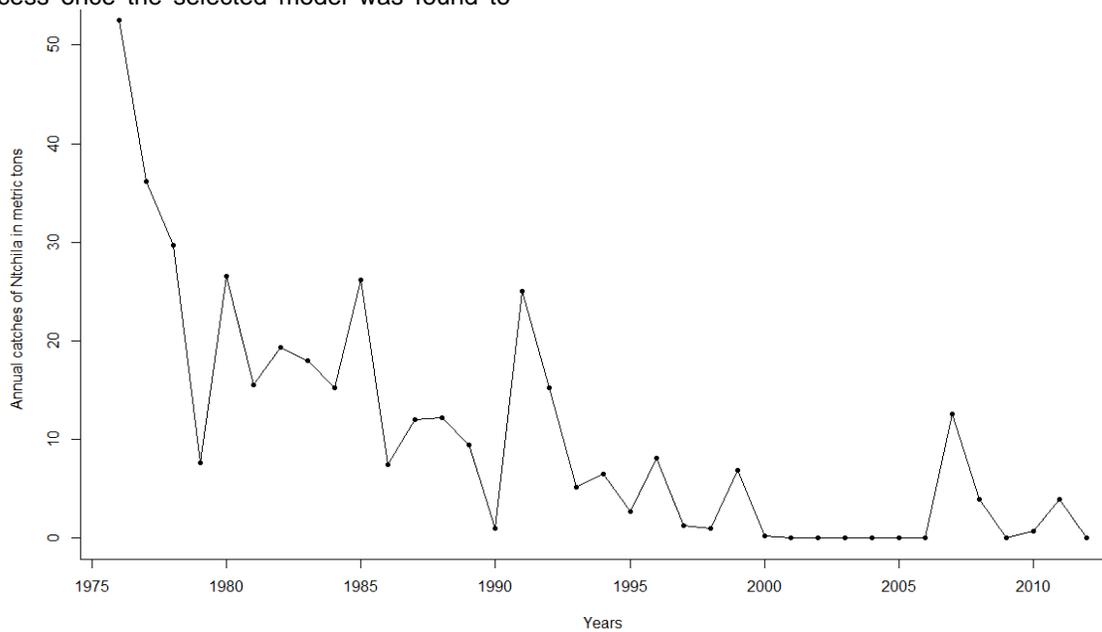


Figure 1: Plotted non stationary annual original *Labeo mesops* catches time series data in metric tonnes from 1976 to 2012 from artisanal fishers of Lake Malawi in Mangochi District.

Autocorrelation function (ACF) plot in Figure 2 showed several non-zero lags that tailed off at lag 4 hence proving that the original series was indeed not stationary.

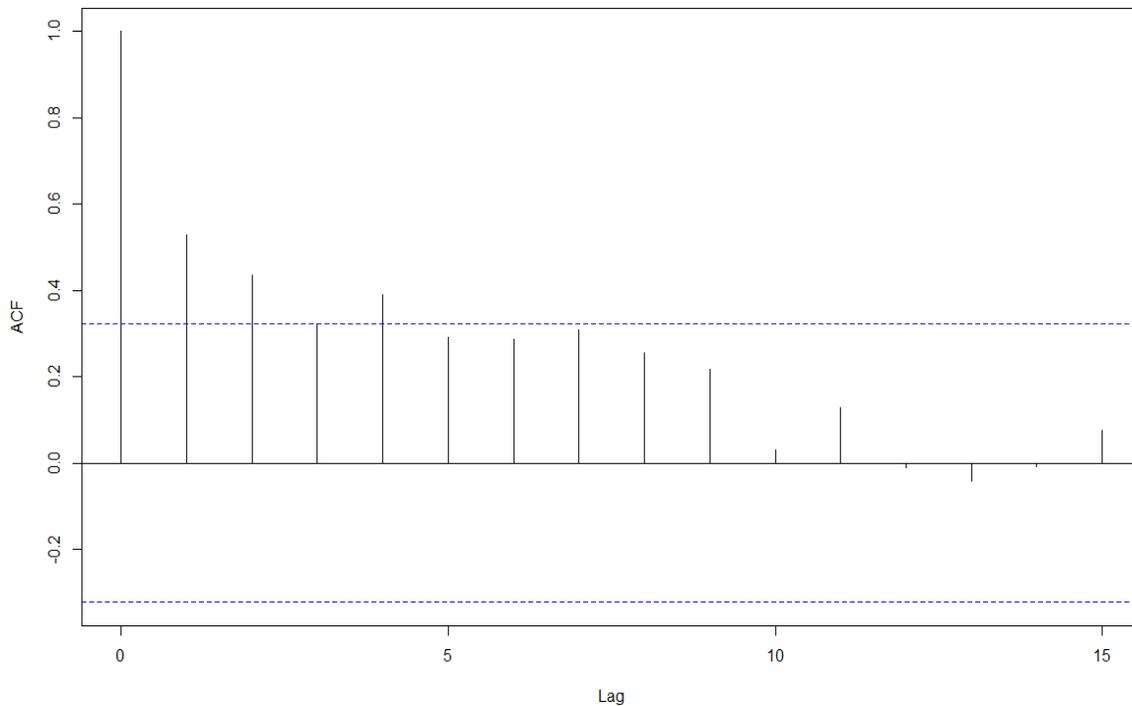


Figure 2: Autocorrelation function generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

Dickey-Fuller test on the original series of the landings of *Labeo mesops* in Table 1 showed that the original data was not stationary and required some form of transformation. The Dickey-Fuller test proved this by giving a *p-value* of 0.52 which demanded the rejection of the stationarity as an alternative hypothesis. The removal of the non-stationarity

was done through differencing. The data was differenced once and the resultant time series proved to be stationary and ready for ARIMA modelling. The graphical analysis method on the plotted differenced time series data showed stationarity as shown in Figure 3, as it showed that it had a constant variance and a mean of zero.



Figure 3: Stationary differenced Ntchila landings series data generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

The Dickey-Fuller test proved the stationarity in the differenced time series data by the smaller *p-value* of 0.01 in Table 1. The Dickey-Fuller test results in Table 1 also showed that the difference time series data was no longer explosive as indicated by the higher *p-value* of 0.99 hence the differenced time series was indeed stationary. The differencing made the new time series values to vary over time with a constant mean and constant variance hence stationary. This implied that the differenced data was ready for modelling and forecasting.

Table 1: Table showing Dickey-Fuller and Augmented Dickey-Fuller Test results on Ntchila catches time series generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

Type of data	Alternative Hypothesis	Dickey-Fuller statistic	Lag order	p-value
Non-differenced data	Stationarity	-2.126	3	0.52
Difference data	Stationarity	-4.5188	3	0.01
Difference data	Explosiveness	-4.5188	3	0.99

$p \geq 0.05$ data is not stationary
 $p \geq 0.05$ data is not explosive hence stationary

Since the new series was successfully proved to be stationary by the Dickey-Fuller test and the graphical analysis method, then autocorrelogram and partial autocorrelogram were plotted to determine the values of *p* and *q* in the ARIMA models. The plotted partial autocorrelation function showed first-order autoregressive

(AR) model as shown in Figure 4 while the plotted autocorrelation function showed eleventh-order moving average (MA) model as shown in Figure 5. The autocorrelogram and partial autocorrelogram, in Figures 4 and 5 were used to identify various competing model.

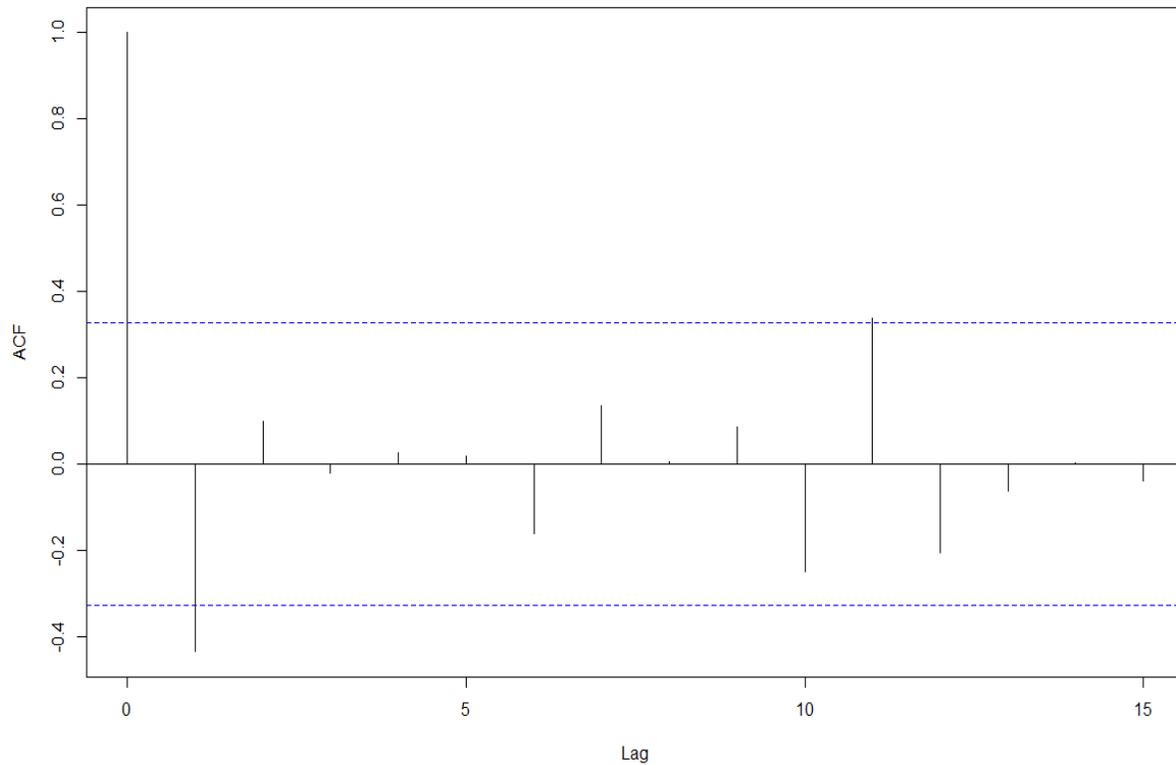


Figure 4: Autocorrelation function of differenced Ntchila landing showing eleventh-order moving average (MA) generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

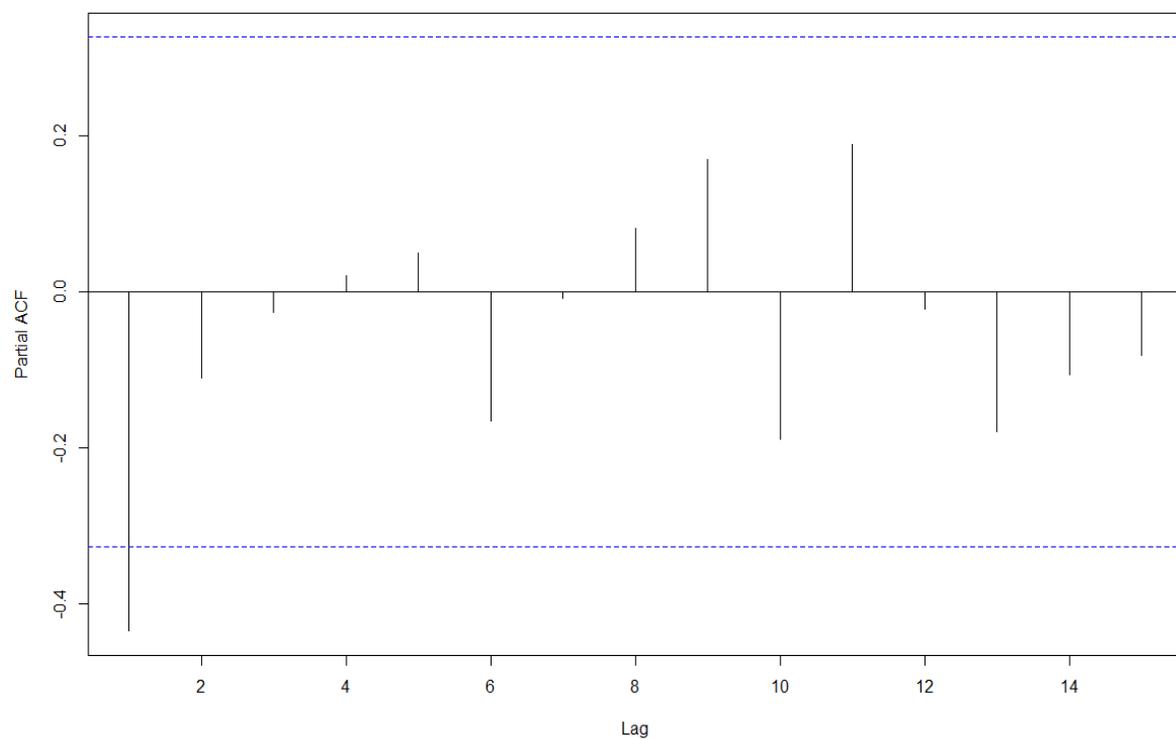


Figure 5: Partial autocorrelation function of differenced Ntchila landing showing first-order autoregressive (AR) model generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

The most competing models identified together with their corresponding fit statistics are shown in Table 2. The model in the ARIMA family with the lowest AIC and BIC values was selected. The value of the AIC of the selected ARIMA model was 250.75 while that of BIC was 255.5 as also shown in the Table 2. Owing to that, the most suitable model for forecasting Ntchira; *Labeo mesops* landings from Lake Malawi in Mangochi District is ARIMA (0, 1, 1), as this model had the lowest AIC and BIC values.

Table 2: Fit statistics for various competing ARIMA models generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

ARIMA (p, d, q)	AIC	BIC
ARIMA (1, 1, 1)	252.75	259.08
ARIMA (1, 1, 0)	252.54	257.29
ARIMA (0, 1, 2)	252.75	259.08
ARIMA (0, 1, 1)	250.75	255.5

Model with the lowest AIC and BIC is the best fit

The Box–Pierce (and Ljung–Box) test also proved that among the four (4) most competing models (0, 1, 1) and

(0, 1, 2) were found to be better fitting models as shown in Figures 6, 7, 8 and 9.

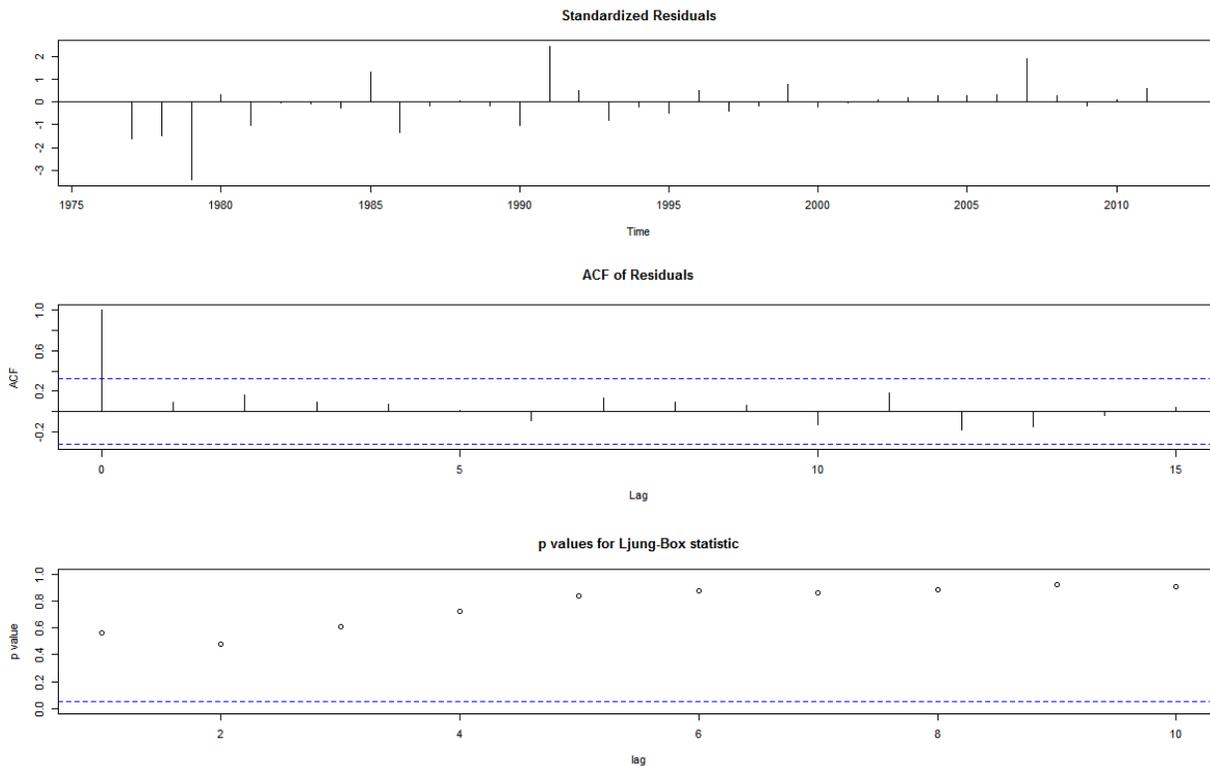


Figure 6: The Box–Pierce (and Ljung–Box) test out-put for ARIMA (1, 1, 1) generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

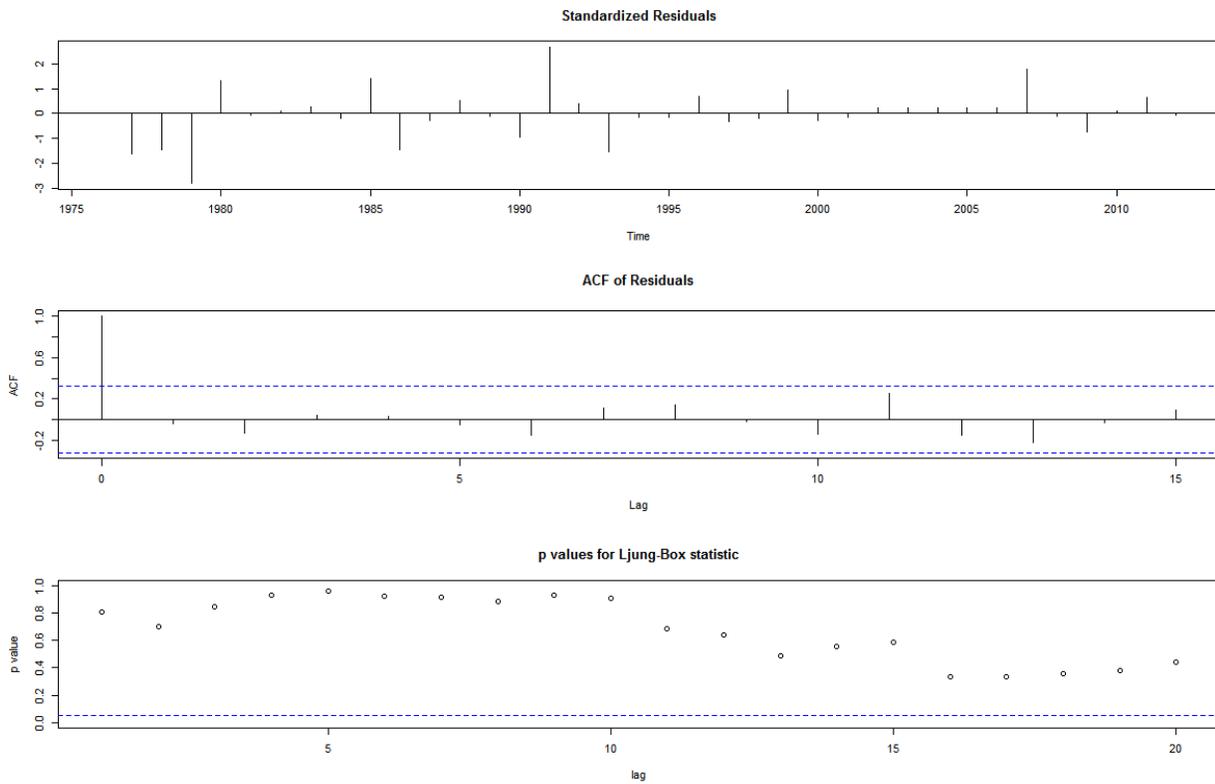


Figure 7: The Box–Pierce (and Ljung–Box) test out-put for ARIMA (1, 1, 0) generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

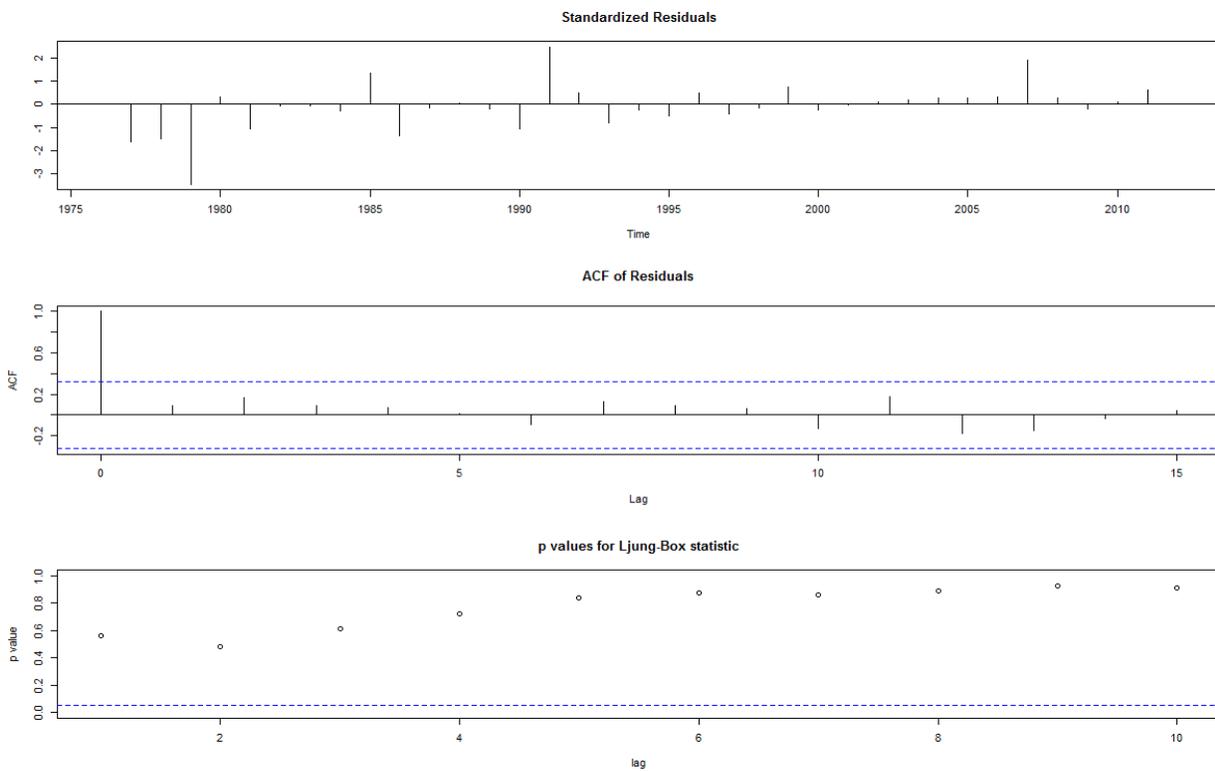


Figure 8: The Box–Pierce (and Ljung–Box) test out-put for ARIMA (0, 1, 2) generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

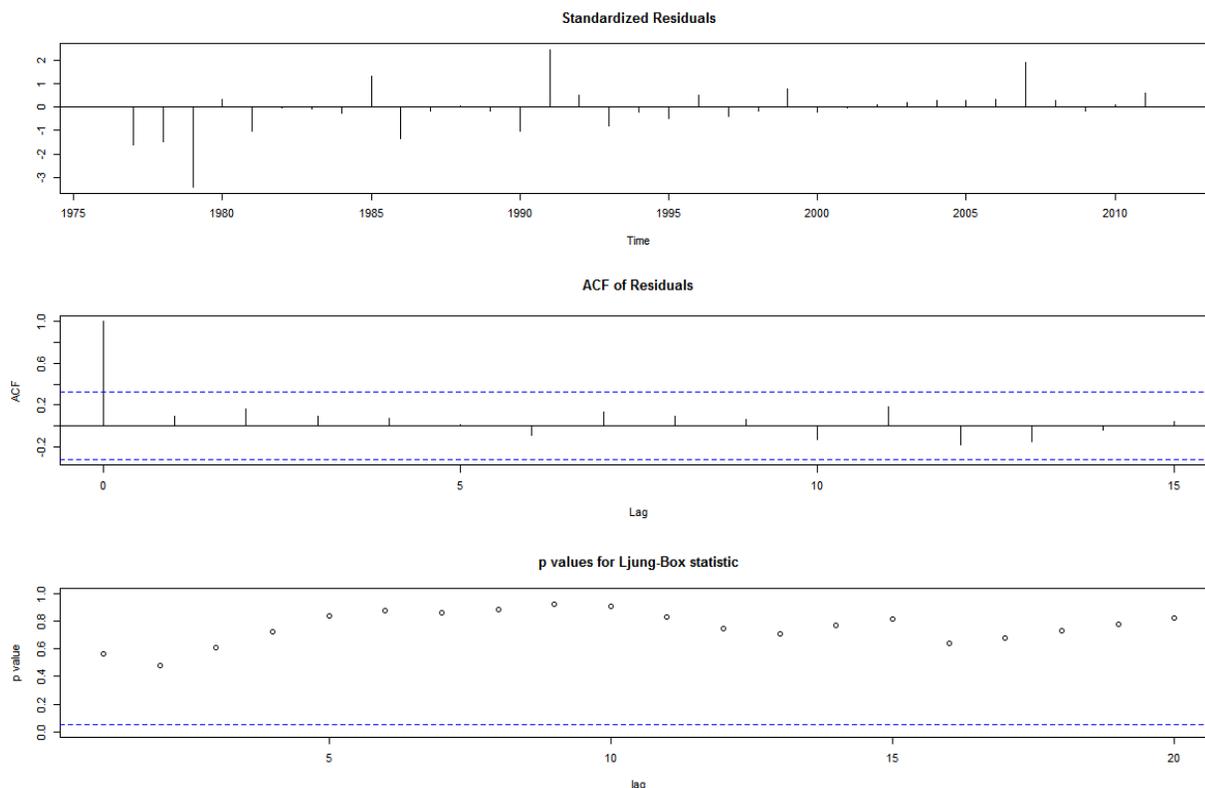


Figure 9: The Box–Pierce (and Ljung–Box) test out-put for ARIMA (0, 1, 1) generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

This implied ARIMA (0, 1, 1) model was still outstanding among the four (4) as in other tests, it out played the ARIMA (0, 1, 2) such as by have lower AIC and BIC values. The Box–Pierce test basically examines the Null of independently distributed residual errors, derived from the idea that the residual errors of a “correctly specified” model are independently distributed (Coghlan, 2015). In a case where the residual errors are not independently distributed,

then it indicates that they come from a miss-specified model.

3.2 Model Estimation

All the analyses of the time series in this study were done by R software version 3.1.3 (2015 – 03 – 09). The software was used to estimate the parameters of the selected models as shown in Table 3.

Table 3: Selected competing models’ parameters with their AIC and BIC generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

	ARIMA (1, 1, 1)	ARIMA (1, 1, 0)	ARIMA (0, 1, 2)	ARIMA (0, 1, 1)
Constant	-1.0435	-1.3038	-1.0437	-1.0437
L1. AR	0.0006	-0.4579		
L1. MA	-0.6445		-0.6438	-0.6440
L2. MA			-0.0005	
AIC	252.75	252.54	252.75	250.75
BIC	259.08	257.29	259.08	255.5

Model with the lowest AIC is the best fit

The model with significant coefficients parameters with least AIC is better in terms of forecasting performance than the one with insignificant coefficients parameters with large AIC (Gutiérrez-Estrada *et al.* 2004, Czerwinski *et al.* 2007). The model had also lowest BIC value. All these tests and examinations proved that the ARIMA (0, 1, 1) model is the

best model to forecasting of the future of artisanal fishers landings of Ntchila; *Labeo mesops* from Lake Malawi in Mangochi District.

3.3 Diagnostic Checks

After identifying ARIMA (0, 1, 1) as the best fitting model, the next step was to forecast the future landings of the artisanal fishers' *Labeo mesops* fishery in Lake Malawi in Mangochi District. However, several diagnostic checks were made on the identified model before the actual forecasting such as examination of the residuals of the model to identify any systematic structure still in it requiring improvement of the selected ARIMA (0, 1, 1) model (Singini *et al.*, 2012, Lazaro and Jere, 2013). The diagnostic checks were also made by examining the autocorrelations and partial autocorrelations of the residual errors of various orders. In this regard, the Box–Pierce (and Ljung–Box) test and residual errors plots were made to see if the residual errors had a mean of zero and were normally distributed. PACF and ACF for residual errors were plotted as shown in

Figures 10 and 11, both of them showed that there were no non-zero lags. This indicated that there were no significant autocorrelations among the residual errors to exceed the 95% significance bounds. The Ljung-Box test also gave a *p-value* of 0.996, indicating that indeed there was no evidence for non-zero autocorrelations in the forecast errors for lags 1-20. The Box–Pierce (and Ljung–Box) test also showed that the model fitted the series very well as the *p-value* was close to one (1) as shown in the Ljung–Box statistic in Figure 9. The time plot of the forecast errors and a histogram made and shown in Figures 12 and 13 respectively proves that the forecast errors have a constant variance and are normally distributed with mean zero (0).

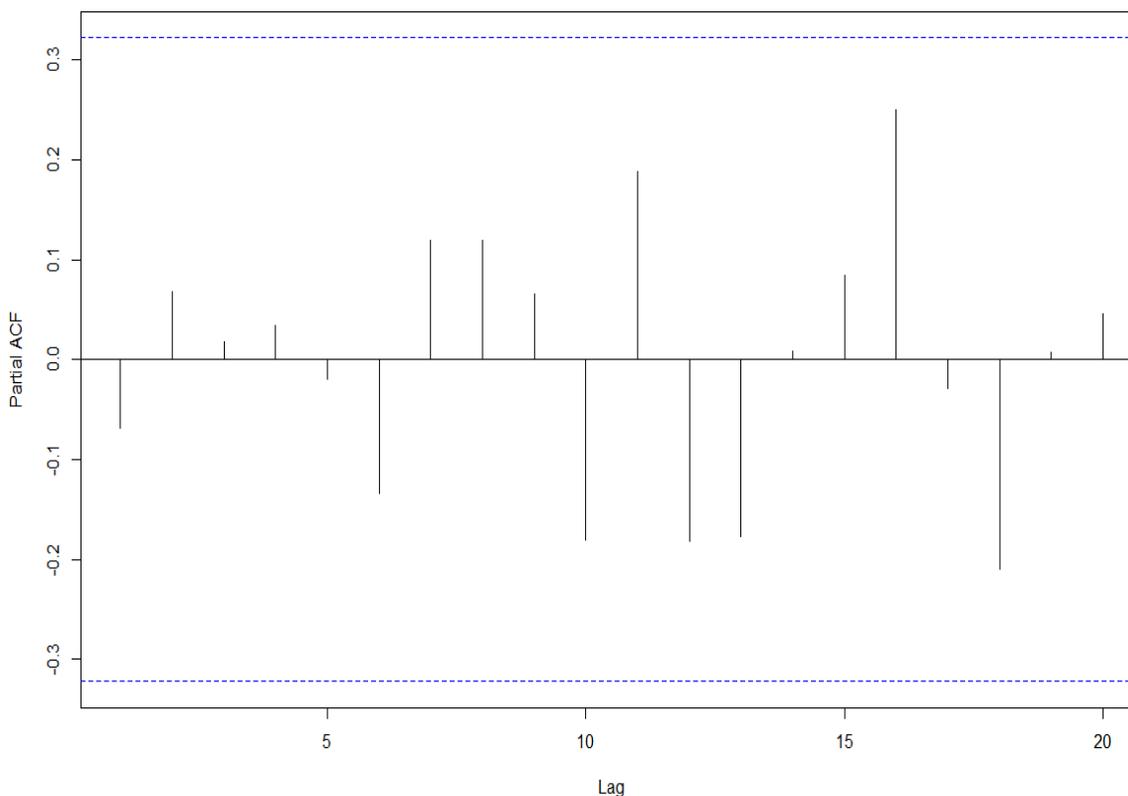


Figure 10: PACF residuals of Ntchila forecasts generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

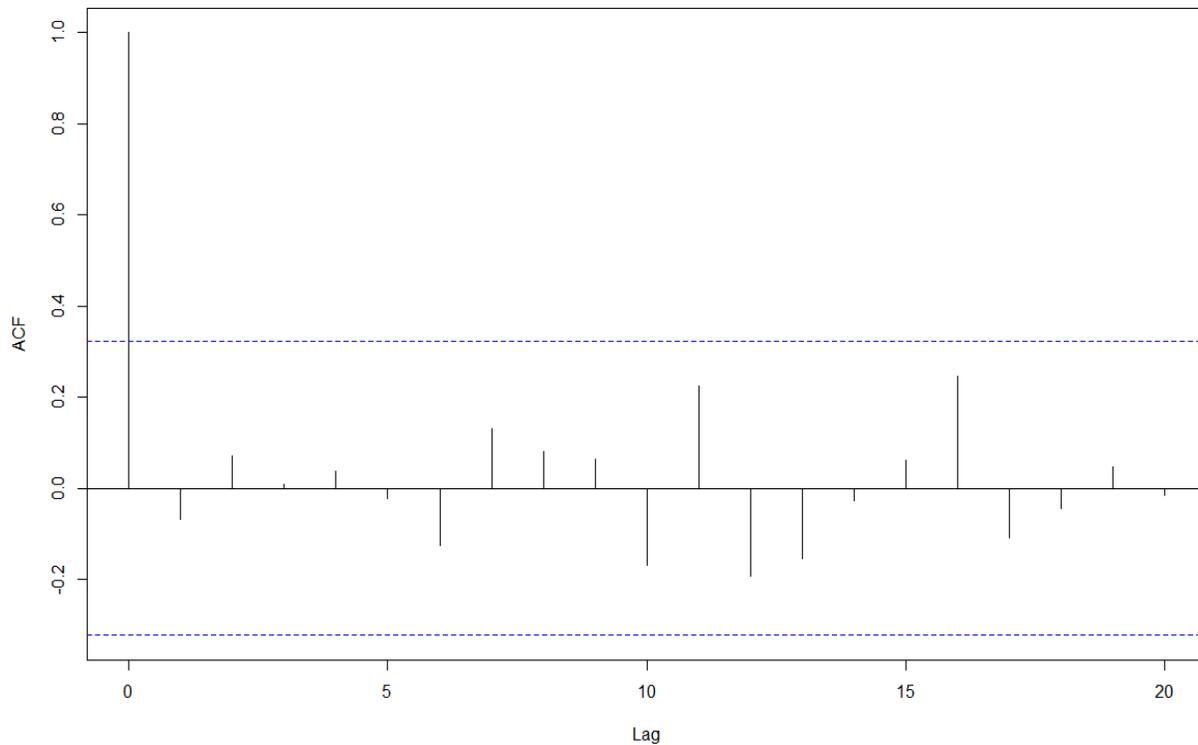


Figure 11: ACF residuals of Ntchila forecasts generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

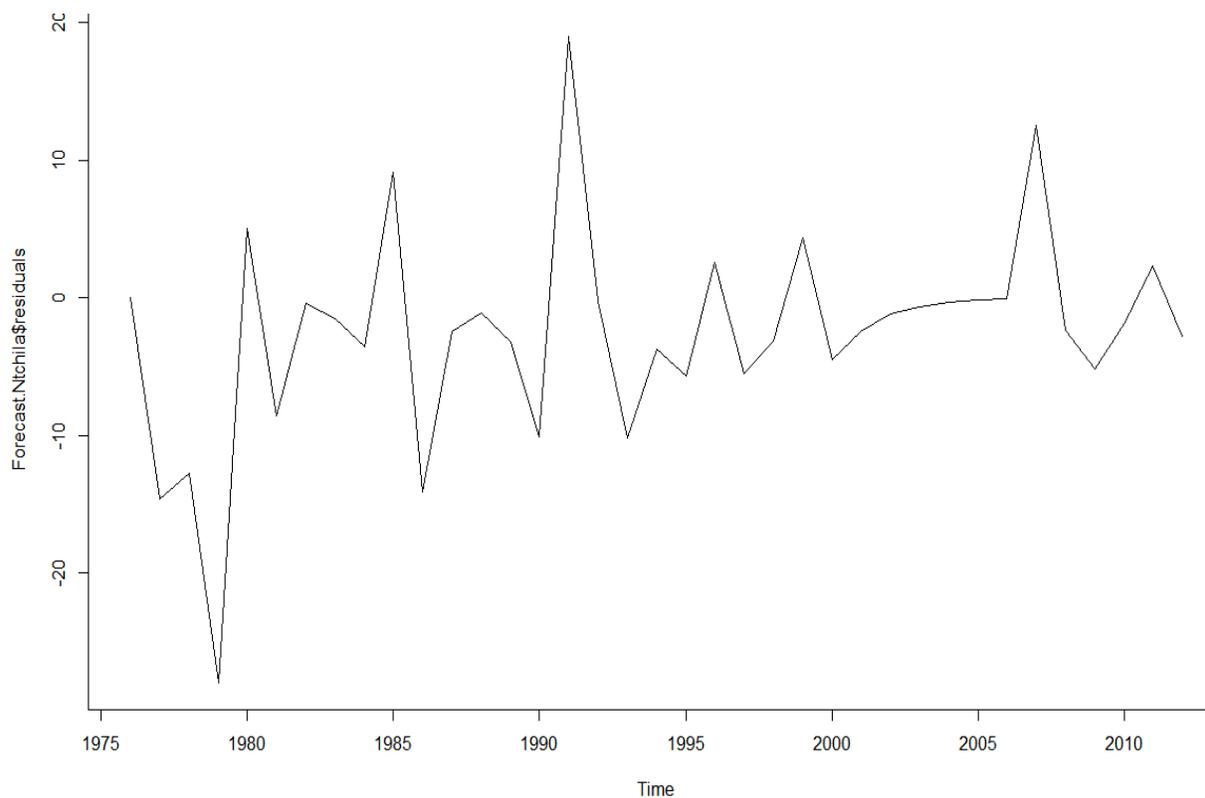


Figure 12: Plot of residuals of forecast of Ntchila landings generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

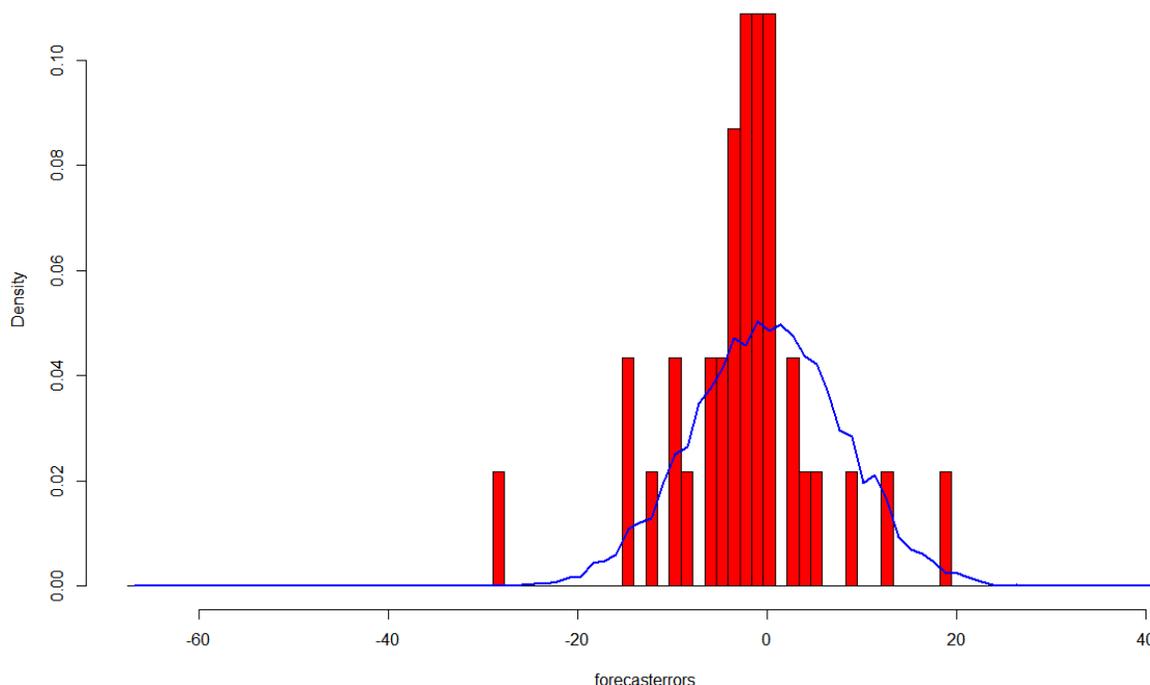


Figure 13: Histogram of forecast errors of Ntchila landings generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

These diagnostic tests proved that the selected ARIMA (0, 1, 1) *Labeo mesops* model was indeed an appropriate model for forecasting landings of the artisanal fishers of Lake Malawi in Mangochi District. The optimum fitted ARIMA (0, 1, 1) model was:

$$x_t = -1.0437 - 0.6440 x_{t-1} \tag{5}$$

3.4 Forecasting

The fitted model was used to forecasts for artisanal landings of Ntchila, *Labeo mesops* of Lake Malawi in Mangochi District from the year 2013 to 2022 at a

confidence interval of 80% and 95% and they included a zero (0) as shown in Table 4. The ability of the model to forecast was tested to check the level of accuracy on the post sample forecasting. The graph in Figure 14 shows actual catches and the forecasted trend with their confidence interval of 80% and 95%. A good model should have a low forecasting error as the case with ARIMA (0, 1, 1), therefore when the distance between the forecasted and actual values are low then the model has a good forecasting power (Czerwinski *et al.*, 2007, Singini *et al.*, 2012, Lazaro and Jere, 2013).

Table 4: Forecast catches of Ntchila, *Labeo mesops* with 80% and 95% confidence intervals for artisanal fishers of Lake Malawi in Mangochi District.

Year	Actual Catches	Forecasted Catches	80% confidence intervals		95% confidence intervals	
2013		-1.17	-11.32134,	8.991421	-16.69780,	14.36788
2014		-1.04	-13.12428,	11.036801	-19.51933,	17.43185
2015		-1.04	-13.12428,	11.036801	-19.51933,	17.43185
2016		-1.04	-13.12428,	11.036801	-19.51933,	17.43185
2017		-1.04	-13.12428,	11.036801	-19.51933,	17.43185
2018		-1.04	-13.12428,	11.036801	-19.51933,	17.43185
2019		-1.04	-13.12428,	11.036801	-19.51933,	17.43185
2020		-1.04	-13.12428,	11.036801	-19.51933,	17.43185
2021		-1.04	-13.12428,	11.036801	-19.51933,	17.43185
2022		-1.04	-13.12428,	11.036801	-19.51933,	17.43185

Where the confidence interval includes a zero (0); extinction of the species cannot be ruled out

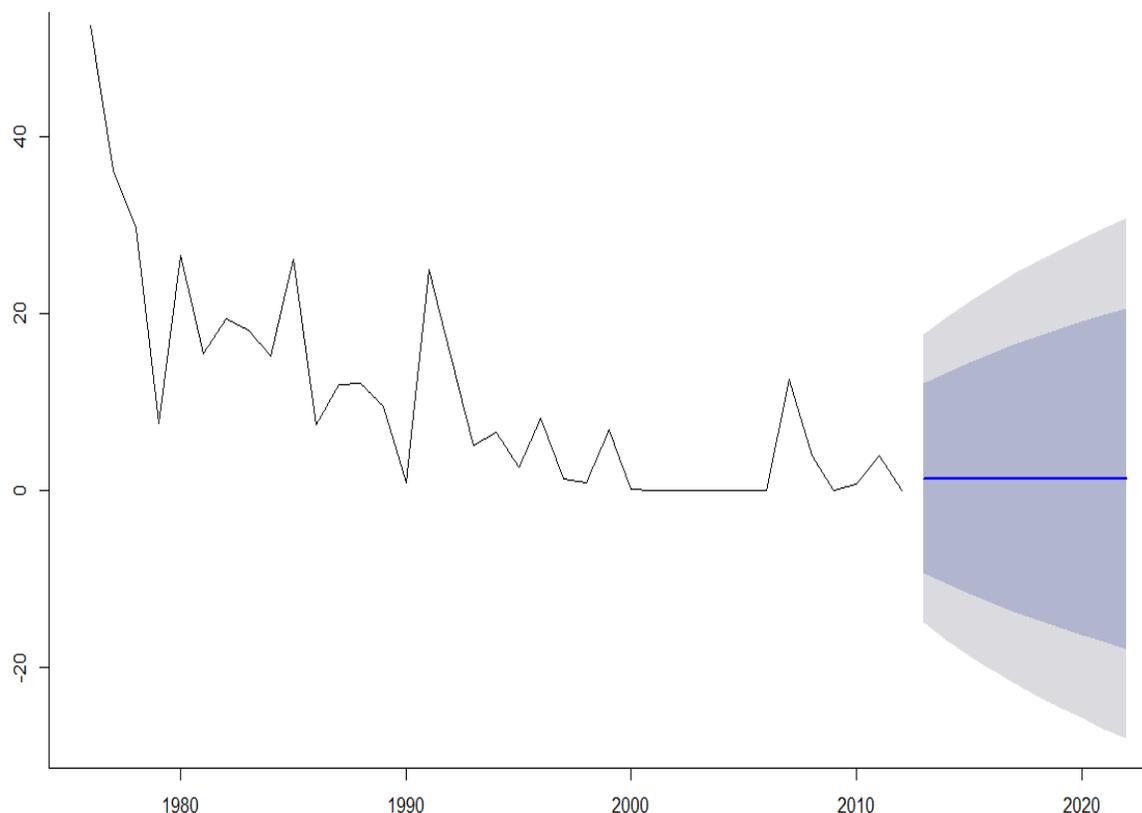


Figure 14: Forecasted artisanal landings of Ntchila, *Labeo mesops* using ARIMA (0, 1, 1) from Lake Malawi in Mangochi District generated from annual *Labeo mesops* catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi in Mangochi District.

The forecast for artisanal landings of Ntchila, *Labeo mesops* from Lake Malawi in Mangochi District had a mean below zero (-1.05 tonnes) and the mean of the actual catches was 10.34 tonnes. The catches in the year 2022 will be below similarly zero with a mean of -1.05 tonnes as shown in Table 4. These results are a clear demonstration that the artisanal fishery of Ntchila, *Labeo mesops* from Lake Malawi in Mangochi District would have already collapsed. This has not come as a surprise as a decline of Ntchila, *Labeo mesops* on Lake Malawi was observed in 1960s (Walker, 1976) and years later. Efforts were made to restore the fishery by establishment of a mass production technique of artificial seed of the Ntchila, *Labeo mesops* in 1986 to restock the water bodies in Malawi with artificially produce juveniles at National Aquaculture Centre at Domasi in Zomba District (Msiska, 1986). In late 1990s, Japan International Cooperation Agency (JICA) funded a project 'Aquaculture Development of Indigenous Species in Malawi' to produce mass artificial seed of Ntchila, *Labeo mesops* to be stock in our water bodies (Morioka *et al.*, 2002). However, the study has established that the fishery of Ntchila, *Labeo mesops* in Lake Malawi in Mangochi District would have already gone extinct hence below the B_{lim} of 20% of B_{max} . This forecast strongly compels policy makers to rethink the current fisheries management system's efficiency in managing and restoring Ntchila, *Labeo mesops* fishery in Lake Malawi in Mangochi District among artisanal fishers. This implies that the current fisheries management are not being effective to sustainably manage the

exploitation of this fishery. The result of this study entails that the management of the *Labeo mesops* fishery could be succumbing to the theory of 'Tragedy of Commons'. The *Labeo mesops* ecology among artisanal fishers in Lake Malawi in Mangochi District is directly linked to other species in the lake hence its collapse might negatively affect others. As such efficient management of Ntchila, *Labeo mesops* in this fishery is very crucial to avoid the forecasted trend negatively affecting other species and restoring this species back to the lake.

4. Conclusion

The ARIMA (0, 1, 1) was generated successfully to forecast the artisanal landings of Ntchila, *Labeo mesops* from Lake Malawi in Mangochi District from the year 2013 to 2022. The forecast for artisanal landings of Ntchila, *Labeo mesops* from Lake Malawi in Mangochi District showed that the species could have already collapsed since the forecast was in negatives. All things constant or worsening in terms of management, fishing pressure, habitat destruction, climate change challenges among others, then the stock of Ntchila would no longer be available by the year 2022 in landings of artisanal fishers of Lake Malawi in Mangochi District.

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