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Research Application Summary

The potential of incorporation of forecasting using time series data into fisheries management in Malawi: Case of management of *Oreochromis* species of Lake Malawi

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Abstract

The Chambo fishery has been reported to be declining over the years to the levels that strategies were put in place to restore the fishery by the government and other stakeholders. The effectiveness of these strategies in restoring the chambo fishery in Lake Malawi in Mangochi District has to be quantified and calls for proper adjustments be made to achieve the goal of restoring the fishery. This study aimed at modelling and forecasting *Oreochromis* species (*Chambo*) yield from artisanal fishery on Lake Malawi in Mangochi District using fish landings data from 1976 to 2012 from the Department of Fisheries in Malawi. The study employed Holt's exponential smoothing model to forecasts the landings from 2013 through 2022. Several diagnostic techniques were employed to validate the generated model, the one that best suited the data was used in the forecasting. The future forecast of the landings showed a mean of -333.981 tonnes (with confidence intervals of 80% and 95%), implying that the fishery would have collapsed. The forecast also showed that in the year 2022 the fishery will have completely collapsed from 1940.08 tonnes in the year 2010 as shown by the negative forecasted fish landings (-1458.30 tonnes) with confidence intervals of 80% and 95% and included a zero (0). These results are clearly demonstrating that the artisanal fishery in focus will completely get collapsed by 2017 despite several management strategies on *Chambo* that have been implemented on Lake Malawi. The forecast also shows that these strategies had limited impact on restoring the fishery. The current fisheries management system on Lake Malawi is species-specific and most of these management systems were crafted around management of *Chambo* fishery. This has unfortunately not worked as envisaged. This forecast strongly calls for revisiting of the fisheries management in this area so as to restore this fishery.

Key words: Artisanal fishery, forecasting, Holt's exponential smoothing model, Lake Malawi, management, modelling, *Oreochromis* species, yield

Résumé

La pêche de *Chambo* (*Oreochromis*) a été rapportée à la baisse au cours des années à tel point que les stratégies ont été mises en place par le gouvernement et d'autres parties prenantes pour restaurer la pêche. L'efficacité de ces stratégies dans le rétablissement de la pêche de *chambo* dans le lac Malawi dans le district de Mangochi doit être évaluée et appelle à des ajustements appropriés pour atteindre l'objectif du rétablissement de la pêche. Cette étude visait à la modélisation et la prévision du rendement de la pêche artisanale des espèces *Oreochromis* (*Chambo*) sur le lac Malawi dans le district de Mangochi en utilisant les données de capture de poissons au débarcadère à partir de 1976 jusqu'en 2012 du ministère des Pêches au Malawi. L'étude a utilisé le modèle de lissage exponentiel de Holt pour prédire des captures au débarcadère à partir de 2013 jusqu'en 2022. Plusieurs techniques de diagnostic ont été utilisées pour valider le modèle généré ; celui qui convient les données le mieux a été utilisé dans la prévision. Les prévisions des captures au débarcadère a montré une moyenne de -333.981 tonnes (avec des intervalles de confiance de 80% et 95%), ce qui implique que la pêche se serait effondrée. Les prévisions ont également montré que, dans l'année 2022 la pêche se sera complètement effondrée des 1940.08 tonnes en 2010, comme le montrent les captures de poissons au débarcadère négatifs prévus (-1458.30 tonnes) avec des intervalles de confiance de 80% et 95% et un zéro (0) inclus. Ces résultats démontrent clairement que la pêche artisanale en question va complètement s'effondrer en 2017 en dépit de plusieurs stratégies de gestion du *Chambo* qui ont été mises en œuvre sur le lac Malawi. Les prévisions montrent aussi que ces stratégies ont eu un impact limité sur la restauration de la pêche. Le système de gestion de la pêche en cours sur le lac Malawi est spécifique à une espèce et la plupart de ces systèmes de gestion ont été conçu autour de la gestion de la pêche du *Chambo*. Cela n'a malheureusement pas fonctionné comme prévu. Cette prévision recommande fortement de revisiter la gestion de la pêche dans cette zone afin de rétablir cette pêcherie.

Mots clés: la pêche artisanale, la prévision, le modèle de lissage exponentiel de Holt, le lac Malawi, la gestion, la modélisation, l'espèce *Oreochromis*, le rendement

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Background

Chambo is a collective local name of *Oreochromis species; Oreochromis lidole* (Trewavas, 1941), *Oreochromis squamipinnis* (Güther, 1984), *Oreochromis saka* (Lowe, 1953) and *Oreochromis karongae* (Trewavas, 1941) all of which are endemic to Lake Malawi (Turner, *et al.*, 1989). It is a very popular fish in Malawi.

In Malawi, about 95% of the annual fish landings target domestic markets due to high demand for fish. However, this does not meet the high demand for the fish. Hence Malawi is a net importer of fish. For instance, from 1997 to 2011, annual fish exports averaged 86 tonnes against an average of 1,400 tonnes of imports. Artisanal fishery accounts for 90% of the total fish landings in Malawi (Government of Malawi, 2012).

Previous studies have shown that the fishery resource on L. Malawi is declining (Bulirani *et al*., 1999; Kanyerere *et al*., 2003; Government of Malawi, 2012), hence posing a doubt on continued provision of fish as an ecosystem services in the future. The chambo fishery is reported to be under threat of extinction (Hara, 2005). Over fishing and increased economic activity are depleting the fish stocks in Lakes of Malawi (Weyl *et. al*., 1999). Without formulation and implementing an appropriate strategy, fish supply in the country will continue to decline against the increasing human population. Consequently, government and non-governmental organizations are working towards ensuring that the fishery resources are sustainably exploited to avoid collapse of part or the whole fishery resource (Government of Malawi, 2012).

Catch per unit effort (CPUE) has been used for many years in assessing catch trends for different fish species in Malawi. However, over the past years, the use of time series models has been recommended as the best method in determining both trends and forecasts in other countries. The time series analysis technique is easy to interpret and allows a detailed assessment of seasonal effects and adequately forecasts production trends and seasonal fluctuations (Lazaro and Jere, 2013). Time series analysis is a well-developed scientific method of analysis that has been extensively and successfully used in fisheries studies around the world as well as other fields such as economics and meteorology (Craine, 2005).

Literature summary

Literature shows that very few researchers have attempted to forecast fish landings in Malawi although large quantities of time series data are available. Singini *et al*. (2012) forecasted small *Haplochromine* species (kambuzi) production in Lake Malawi, while Lazaro and Jere (2013) forecasted commercial chambo (*Oreochromis* species) fishery in Lake Malawi.

The fish landings data used in this study fitted very well Holt's exponential smoothing method to forecast it. This method is basically an extension of a moving average (MA) process and generate forecasting by *weighted* moving average. For this, the Holt's exponential smoothing method is said to be an extension of the single exponential smoothing to linear exponential smoothing that allows forecasting of time series with *trends*. The smoothing concept assumes that more recent values are more important than oldest values when it comes to forecasting. Holt's exponential smoothing method smoothes the trend and slope directly by using different smoothing constants, alpha and beta (Hanke and Reitsch, 1998). The predictive, Holt's exponential smoothing model developed is checked if it requires improvement by checking whether the in-sample forecast errors show non-zero autocorrelations at lags 1-20 and by using Ljung-Box test (Craine, 2005).

The Holt's exponential smoothing models are widely used because the method is easy to understand and determining the appropriate parameters hence less complicated than for instance ARIMA models (Gooijer and Hyndman, 2006). A good candidate of the Holt's exponential smoothing model should have the forecast errors with constant variance over time and should be normally distributed with mean zero. Taylor (2008), reported that the overall accuracy of forecasts made with the exponential smoothing method are very good hence the forecast of Holt's exponential smoothing method can be trusted.

Study description

This study was carried out on Lake Malawi in Mangochi District on all seven (7) minor strata namely 2.1, 2.2, 2.3, 2.4, 2.5, 2.6 and 3.1, only involving the artisanal fishery while excluding the commercial fishery. Data were collected using two data collection system; catch assessment survey (CAS) and Malawi traditional fisheries (MTF). The data that have been used in this study are univariate time series of total fish catch of *Oreochromis* species (Chambo) from artisanal fishery of Lake Malawi in Mangochi District from 1976 to 2012 obtained from Monkey Bay Fisheries Research Unit of the Department of Fisheries of Malawi. The unit of measurement used in this study was metric tonnes and refers to the wet weight of fish at the time it was fished out of water.

Holt's exponential smoothing is very useful when forecasting data which is stationary but has no non-zero lags (Coghlan, 2015). For this principle the differenced *Oreochromis* species (Chambo) yield data fitted very well to Holt's exponential smoothing modelling as it had no significant lags on both autoregressive (AR) and moving average (MA). Holt's exponential smoothing modelling estimates the level and slope at the current time point (Coghlan, 2015). Smoothing was done by estimating the level at the current time point denoted by á (alpha) and estimating the slope b of the trend component at the current time point denoted by â (beta). The parameters á and â had values between 0 and 1, and values that are close to 0 meant that little weight was placed on the most recent observations when making forecasts of future values as also reported by Coghlan (2015).

Once alpha and beta were estimated, then the original time series was plotted together with the forecasted values (fish landings) at a time point in different colours to be easily traced. This was aimed at checking to what extent the fitted Holt's exponential smoothing model best fit the original time series. Once the results were satisfying for a best fit of the Holt's exponential model, the model was used to forecast short term in the future. The parameters generated during parameter estimation stage are used to get the forecasted value ($Ft + m$). The Holt's exponential smoothing method was represented by a set of models as shown below:

Level: $$L_t = \alpha Y_t + (1 - \alpha)(L_{t-1} + b_{t-1}) \quad (1)$$

Trend: $$b_t = \beta(L_t - L_{t-1}) + (1 - \beta) b_{t-1} \quad (2)$$

Forecast: $$F_{t+m} = L_t + b_t m \quad (3)$$

Where: F_{t+m} represents the forecast m periods ahead, L_t denotes an estimate of the level of the series at time t and b_t is an estimate of the slope of the series at time t. The first model directly adjusted L_t for the last smoothed value (L_{t-1}) by adding it to the trend of the previous period (b_{t-1}). The second model updated the trend, which is expressed as the linear difference between the last two smoothed values.

The trustworthiness of the developed model was tested by checking whether the in-sample forecast errors showed non-zero autocorrelations at lags 1-20. In this regard a correlogram was made and Ljung-Box test was carried out. It was not enough to check the accuracy of the time point forecast only but also how much the forecasted values could be trusted as well. This was achieved by also checking that the forecast errors are normally distributed with a mean zero and had constant variance over time. This was done by making a time plot of forecast errors, and a histogram of the distribution of forecast errors with an overlaid normal curve according to (Coghlan, 2015).

Research application

The fitted Holt's exponential smoothing model was used to forecast artisanal landings of Chambo, *Oreochromis* species of Lake Malawi in Mangochi District from the year 2013 to 2022 with a confidence interval of 80% and 95% which included a zero (0) as shown in the Table 1 and Figure 1. The forecasted and actual values were close implying that the forecasted errors were low, meaning that the developed model is a good model according to Czerwinski *et al*. (2007), Shitan *et al*. (2008), Singini *et al*. (2012) and Lazaro and Jere (2013).

The chambo species (*O. karongae, O. lidole* and *O. squamipinnis*) are extremely susceptible to overexploitation because of their life history characteristics (Weyl, 1999). The chambo, *Oreochromis* species have low natural mortality rates, long lifespan, late maturity and extended parental care (Palsson *et al.,* 1999). These characteristics makes the species advantaged to have relatively stable population sizes, and catch levels (Adams, 1980). However, the results of this study showed that fishery of chambo is under extinction or quickly going towards the same. This implies that the greater contribution of this collapse is from overfishing as the species have very low natural mortality.

Table 1. Forecast catches of Chambo, *Oreochromis* species with 80% and 95% confidence intervals for artisanal fishers of Lake Malawi in Mangochi District generated from annual *Oreochromis* species catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi, Mangochi District

Year actual catches	Forecasted catches	80% confidence intervals		95% confidence intervals	
2013	790.34	-218.3097	3334.536	-1158.69	4274.92
2014	540.49	-756.37,	2337.05	-1575.14	3155.83
2015	290.64	-3298.97	3880.26	-5199.20	5780.49
2016	40.79	-4642.75	4724.34	-7122.07	7203.66
2017	-209.06	-6053.26	5635.15	-9146.99	8728.88
2018	-458.91	-7531.20	6613.39	-11275.05	10357.24
2019	-708.75	-9075.27	7657.76	-13504.24	12086.72
2020	-958.60	-10683.46	8766.25	-15831.48	13914.27
2021	-1208.45	-12353.63,	9936.72	-18253.52	15836.62
2022	-1458.30	-14083.66,	11167.06	-20767.12	17850.52

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

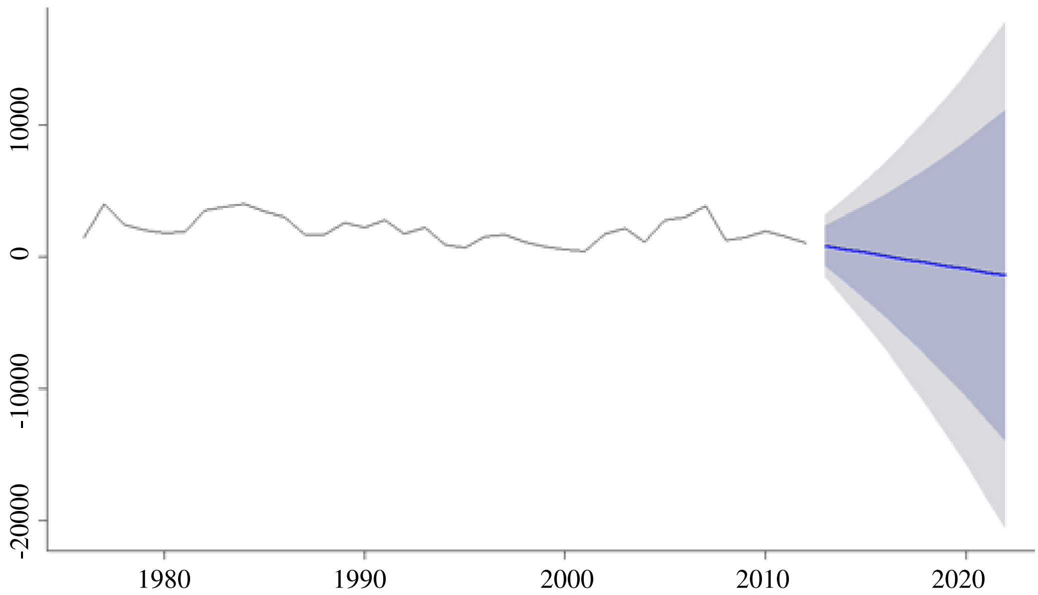

Figure 1. Forecasts of Chambo *Oreochromis* species artisan landings from Lake Malawi in Mangochi District generated from annual *Oreochromis* species catches in metric tonnes from 1976 to 2012 from artisanal fishers from Lake Malawi, Mangochi District

The forecast for artisanal landings of Chambo, *Oreochromis* species from Lake Malawi in Mangochi District showed a mean of -333.981 tonnes implying that the fishery would inevitably collapse. This result compared very well with what Lazaro and Jere (2013) reported on collapse of commercial chambo fishery on Lake Malawi in Mangochi District. The FAO, (1993), Palsson *et al.* (1999) and Department of Fisheries (1999) reported that the Chambo, *Oreochromis* species could be going towards collapsing due to increased fishing. The total catches for chambo showed a steady decline since early 1990s and were reported to be 600 tonnes in 1999 from 4,000 tonnes in 1970s from the south east arm of Lake Malawi in Mangochi District (Manase *et al*., 2002). This showed that the problem of overfishing fueled by poor enforcement mechanism worsened the decline of Chambo in 1990s which has made and will make the fishery fail to rejuvenate and be restored according to the forecast results of this study. Hara (2005) admitted that chambo fishery had collapsed in the south east arm of Lake Malawi and gave the reasons behind the collapse as resource and budgetary constraints, the regime's lack of expediency and legitimacy among users, and the use of technical regulations as a regulatory framework.

The forecast also showed that in the year 2022, the fishery will completely have collapsed from 1940.08 tonnes in the year 2010 as shown by the negative forecasted fish landings and a confidence interval which included a zero (0). It might require a great effort to restore the fishery. Weyl (1999) reported that once the fishery of Chambo becomes overfished, it would require a relatively long period of time for the stocks of the species to rebuild (depending on the extent of overfishing), due to the longevity, slow growth and high age at maturity inherent to these stocks. This makes the forecast results of this study very serious and critical, if we are to save the fishery of chambo.

The Department of fisheries in 1999 through its management report estimated B_{curr} at 32% of B_{max} (already below B_{lim} which the Department of Fisheries slated at 45% of B_{max}), a situation which called for urgent management of the stocks then, hence the reason for implementation of several chambo restoration programs which this study found to be inefficient. The inefficieny of the chambo restoration programs are more likely as a result of poor implementation of these programs by the Department of Fisheries. However, this study's forecast results showed that the situation has worsen from the case in 1990s hence B_{curr} at the moment should be barely above or even below 20% of B_{max} which the Department of Fisheries regards in its policies as a stock very seriously depleted and even in danger of a collapse.

The forecast results of this study are a clear demonstration that the artisanal fishery of Chambo, *Oreochromis* species from Lake Malawi in Mangochi District will completely get collapsed by 2017. This sadly comes when several management strategies of chambo were implemented before on Lake Malawi such as *The Chambo Restoration Strategic Plan*. This implies that the strategies currently implemented are and were not effective. This forecast strongly calls for adjustment in the implementation of the fisheries management in this area from the current system. A potential chambo fishery management on Lake Malawi in Mangochi District should centre around management of two fishing gears; gillnets and chambo seines which account for 65% and 23% of the total chambo catch, respectively while kambuzi and chilimila only contributes 5% (Manase *et al*., 2002).

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