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USING ARTIFICIAL NEURAL NETWORKS FOR PREDICTING NEW BILHARZIA CASES IN CHILDREN AGED 15 YEARS AND BELOW AT GWERU PROVINCIAL HOSPITAL IN ZIMBABWE

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ABSTRACT
Bilharzia is an important, and yet neglected, infectious disease affecting at least 100 million people in Africa. Children in Zimbabwe, just like other children of Africa, continue to carry the heaviest burden of infection, with children as young as 12 months old showing signs of infection. This paper uses monthly time series data on bilharzia cases recorded and managed at Gweru Provincial Hospital (GPH) from Janaury 2010 to December 2019, in order to make predictions over the period January 2020 to December 2021. The study employed the famous ANN (12, 12, 1) model. Residual analysis of this model showed that the model is stable and thus suitable for predicting bilharzia cases at GPH over the out-of-sample period. The findings of this study indicate that bilharzia cases will continue on an upwards trajectory within the GPH catchment area. The study, amongst other policy directions; recommends prompt administration of antiparasite treatment (that is, praziquantel (PZQ)) to all infected children.

INTRODUCTION
Bilharzia, also called Schistosomiasis is caused by schistosomes, which are parasitic trematode worms of the genus Schistosoma. Five species infect humans, namely: Schistosoma mansoni, Schistosoma japonicum, Schistosoma mekongi, Schistosoma intercalatum, and Schistosoma haematobium. In at least 74 countries where the disease is endemic, approximately 250 million people are infected and nearly 700 million people are at risk of infection (Steinmann et al., 2006). Approximately 300000 people die annually from bilharzia in Africa alone (Looman et al., 2003). Schistosoma haematobium infection is a significant cause of clinical morbidity and disability in the endemic countries of Africa and as well as the Middle East, where more than 110 million people are infected (Gentile et al., 2006). In sub-Saharan Africa, two-thirds of bilharzia cases are due to Schistosomiasis haematobium, which represents an important cause of the urinary tract disease (Looman et al., 2003).

Schistosoma haematobium and Schistosoma mansoni are prevalent in Zimbabwe to levels that make schistosomiasis a significant public health problem (Midzi et al., 2011; Chimbari, 2012; Midzi et al., 2014; Mutsaka-Makuvaza et al., 2018; Mutsaka-Makuvaza et al., 2019). In fact, the two forms bilharzia are prevalent countrywide and their epidemiology has already been examined extensively (Taylor & Makura, 1985; Chandiwana & Woolhouse, 1991; Ndhlovu et al., 1992; Hagan et al., 1994; Midzi et al., 2011). The distribution of bilharzia prevalence in Zimbabwe indicates a close nexus with variability of surface water, especially in North Eastern Zimbabwe, which has the highest temperature and rainfall, and, where most streams have some water all year round, the prevalence of Schistosoma mansoni and Schistosoma haematobium is at its highest (Woolhouse & Chandiwana, 1990).

Children in Zimbabwe, especially those aged between 5 and 15 years old, are usually exposed to infective water (Brouwer et al., 2004; Stothard & Gabrielli, 2007; Mduluza & Mutapi, 2017). Even children aged below 5, are also, increasingly becoming exposed to infective water, especially in African countries (Mafiana et al., 2003; Souza-Figueiredo et al., 2008; Uneke & Egede, 2009; Garba et al., 2010) including Zimbabwe (Mutapi et al., 2011; Mduluza & Mutapi, 2017; Mutsaka-Makuvaza et al., 2018; Mutsaka-Makuvaza et al., 2019). The study will model and forecast bilharzia cases in children under the age of 15 years, recorded and managed at GPH. Forecasting models such as ours are of great importance as they can be used to guide clinical treatment and help to select the right medical decisions. As argued by Zhou et al. (2016), forecasting is a powerful tool to facilitate the development of effective control strategies for schistosomiasis that has frequent fluctuations. Our forecasting model will go a long way in helping the GPH health executive in understanding the trends and future evolution of bilharzia in children under the age of 15 years. The findings of the study are also envisioned to help GPH clinicians in making feasible treatment decisions and also determining the urgency of treatment as well as prevention.

OBJECTIVES OF THE STUDY

i. To assess new bilharzia cases in children aged 15 years and below at GPH over the period January 2010 to December 2019.
ii. To predict bilharzia cases for GPH over the period January 2020 to December 2021.
iii. To determine whether bilharzia cases are increasing or decreasing for GPH over the out-of-sample period.

RELATED STUDIES

In a survey conducted in Zvishavane district, Makaka & Nsingo (2012) examined the prevalence and risk factors of urinary and intestinal schistosomiasis over the period March to November 2010. The study revealed that Schistosomiasis haematobium prevalence was higher (60.4%) than Schistosomiasis mansoni prevalence (6.8%). In a country-wide cross-sectional survey, Midzi et al. (2014) investigated the distribution of schistosomiasis and Soil Transmitted Helminthiasis (STH). The study found out that schistosomiasis was more prevalent country-wide (22.7%) than STH (5.5%). Makaka & Nsingo (2012) and Midzi et al. (2014) agree that schistosomiasis prevalence in the country is seasonal (according to weather patterns) and that the prevalence of the neglected disease is gradually increasing and is driven by continuous dam constructions in the country, among other factors. Applying Autoregressive Integrated Moving Average (ARIMA) and the Nonlinear Autoregressive Neural Network (NARNN) as well as ARIMA-NARNN models, Zhou et al. (2016) forecasted the annual prevalence of human schistosomiasis in Yangxin County in China. The study established that the ARIMA-NARNN model performed better and can be applied to analyze surveillance data for early warning systems for the control and elimination of schistosomiasis. Yu et al. (2019) predicted the incidence of schistosomiasis in China using SARIMA and NARX models based on a data set covering the period January 2011 to May 2018. The mixed model, the NARX-SARIMA model was found to have better applicability based on its fitting capability.

METHODOLOGY

This study employed the Artificial Neural Network (ANN) approach in modeling and forecasting monthly bilharzia case volumes at GPH. In line with Fischer & Gopal (1994), who argued that no strict rules are laid down for the determination of the ANN structure; the research applies the famous ANN (12, 12, 1) model based on the hyperbolic tangent activation function.

Data Issues

This study is based on newly diagnosed monthly bilharzia cases (reffered to as B series in this study) in children aged 15 years and below at GPH. The data covers the period January 2010 to December 2019 while the out-of-sample forecast covers the period January 2020 to December 2021. All the data employed in this paper was gathered from GPH Health Information Department.

FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

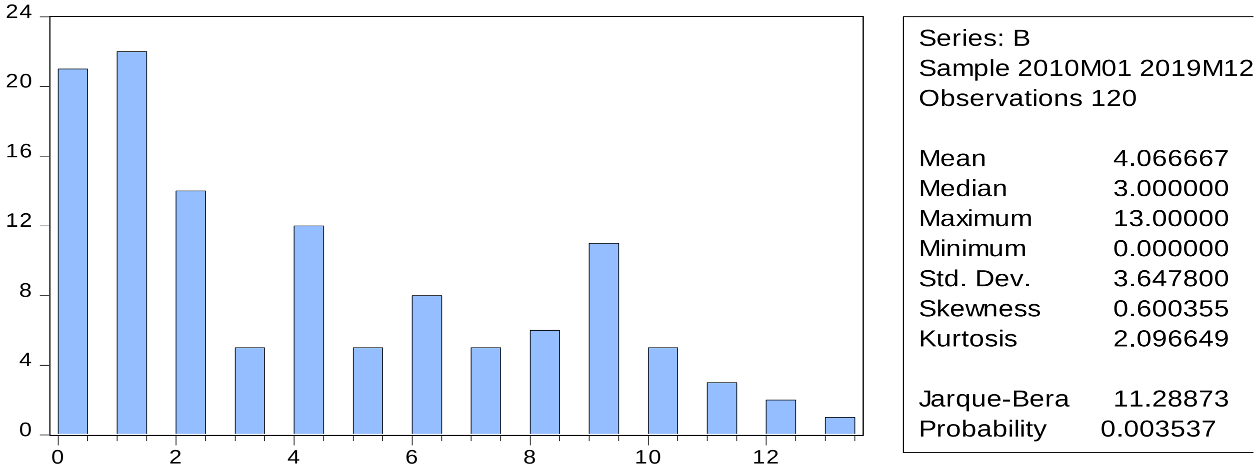


Figure 1: Descriptive statistics

ANN Model Summary for Bilharzia Cases at GPH

Table 1: ANN model summary

Variable	B
Observations	108 (After Adjusting Endpoints)
Neural Network Architecture:	
Input Layer Neurons	12
Hidden Layer Neurons	12
Output Layer Neurons	1
Activation Function	Hyperbolic Tangent Function
Back Propagation Learning:	
Learning Rate	0.005
Momentum	0.05
Criteria:	
Error	0.081576
MSE	0.347108
MAE	0.493625

Residual Analysis for Bilharzia cases

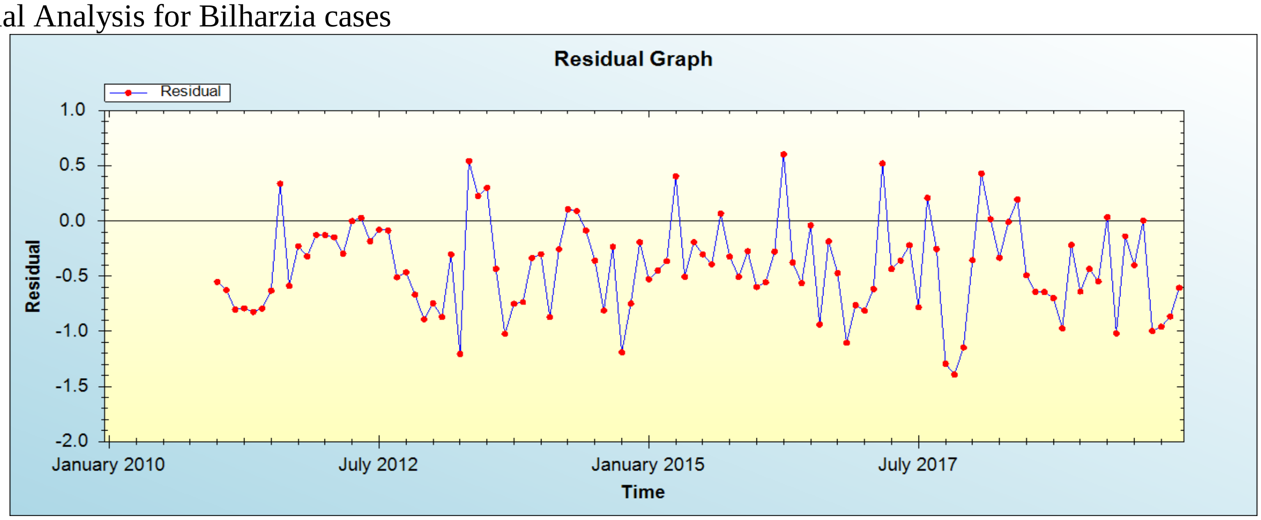


Figure 2: Residual analysis for Bilharzia cases

In-sample Forecast for B

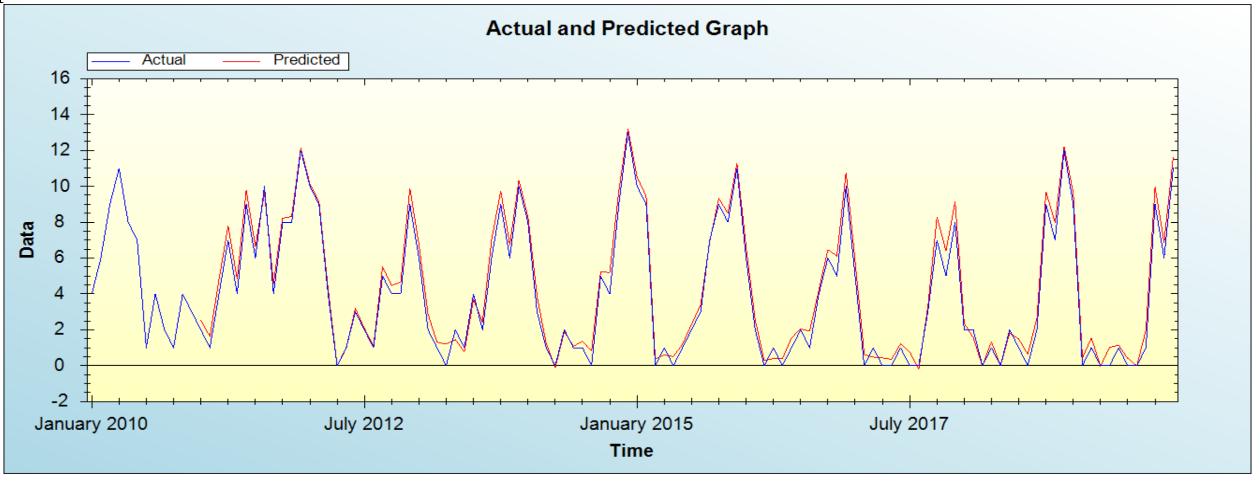
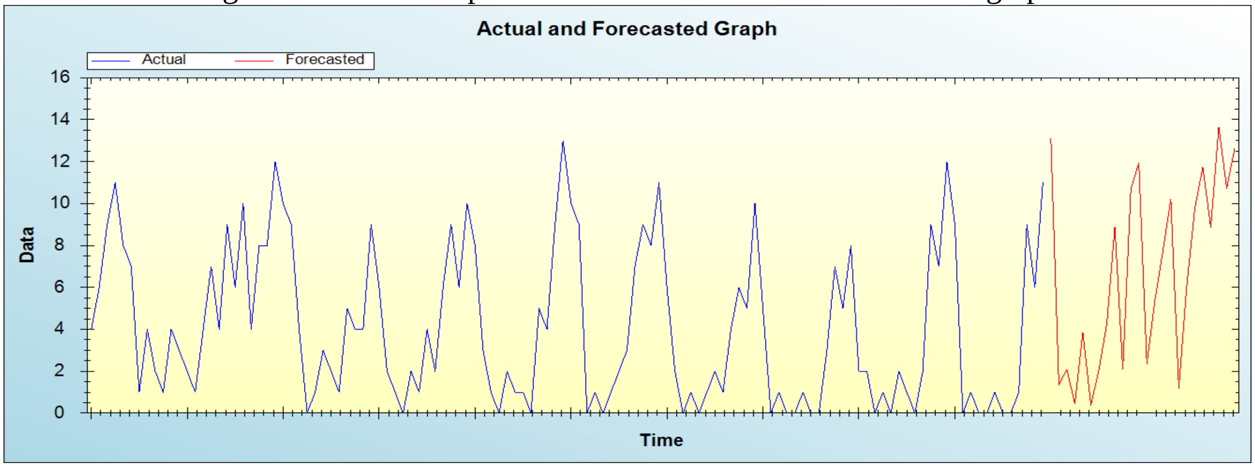


Figure 3: In-sample forecast for the B series

Out-of-Sample Forecast for B: Actual and Forecasted Graph

Figure 4: Out-of-sample forecast for B: actual and forecasted graph



Out-of-Sample Forecast for B: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Month/Year	Predicted B
January 2020	13.0943
February 2020	1.3515
March 2020	2.0982
April 2020	0.4522
May 2020	3.8429
June 2020	0.3838
July 2020	2.0356
August 2020	4.2749
September 2020	8.8958
October 2020	2.1172
November 2020	10.6798
December 2020	11.9368
January 2021	2.3370
February 2021	5.3402
March 2021	7.7007
April 2021	10.1983
May 2021	1.1731
June 2021	6.1025

July 2021	9.7544
August 2021	11.7284
September 2021	8.8641
October 2021	13.6361
November 2021	10.7308
December 2021	12.6442

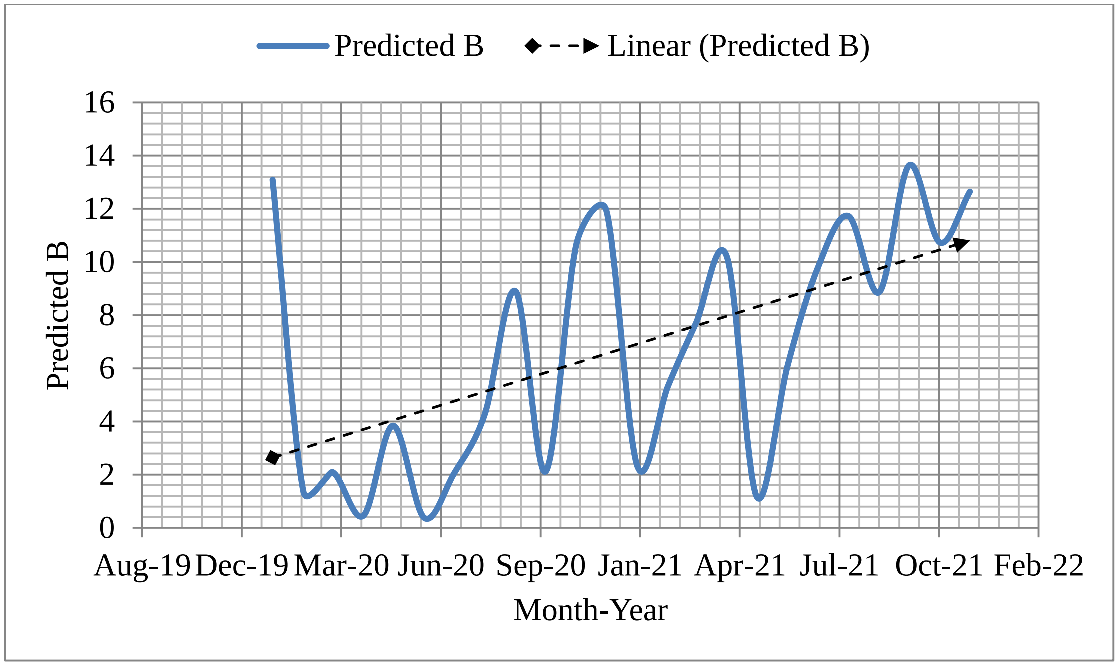


Figure 5: Graphical presentation of out-of-sample forecasts

DISCUSSION OF THE RESULTS

Figure 1 shows the descriptive statistics of the series under consideration. Over the period under study, an average of 4 children per month has been diagnosed with schistosomiasis at GPH. Table 1 is the summary of the ANN (12, 12, 1) neural network model, which has been based on the hyperbolic tangent function as its activation function. The "criteria" are the evaluation statistics and they all point to the fact that the model is adequate. Figure 2 shows the residuals of the applied model and given that the residuals are as close to zero as possible, the model is indeed stable and acceptable for generating forecasts of schistosomiasis case volumes at GPH. Figure 3 shows the in-sample forecast of the model and it is quite clear that the model fits well with data. Figure 4, table 2 and figure 5 are out of sample predictions. The findings of this study indicate that bilharzia cases will continue on an upwards trajectory within the GPH catchment area. These results are consistent with previous studies such as Makaka & Nsingo (2012) and Midzi et al. (2014). These results are simply an early warning signal for the control and elimination of bilharzia not only the GPH catchment area but also in the entire country at large.

CONCLUSION & RECOMMENDATIONS

Bilharzia, a parasitic neglected tropical disease continues to be a significant cause of morbidity and mortality around the globe and Zimbabwe is definitely not an exception. Indeed, for so many decades, bilharzia has actually been among the top ten causes of hospital admissions in the country, which is an overwhelming proof of its public health importance. To better aid the ultimate goal of bilharzia control in the country, we applied a forecasting model, the ANN(12, 12, 1) model; and consequently analyzed the monthly cases and future trends of this neglected public health scourge. The study established that bilharzia cases in children below the age of

15 years are likely to rise over the out-of-sample period. The following two-fold policy recommendations are therefore put forward:

i. GPH should make sure that they have enough stock of drugs (that is antiparasite treatment, namely: praziquantel (PZQ)) to treat infected children.
ii. There is need for educational campaigns, especially to parents; about the exposure of children to schistosomiasis.

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