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USING ARTIFICIAL NEURAL NETWORKS FOR PREDICTING NEW DOG BITE CASES AT GWERU PROVINCIAL HOSPITAL IN ZIMBABWE

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Abstract:

Believe it or not, any dog is capable of biting. Dog bites can cause serious injuries and even death, especially to humans. This piece of work uses monthly time series data on dog bite cases recorded and managed at Gweru Provincial Hospital (GPH) from Janaury 2010 to December 2019, to predict dysentery cases over the period January 2019 to December 2020. The study applied the ANN (12, 12, 1) model. Residual analysis of this model indicates that the model is stable and adequate and therefore suitable for predicting dog bite cases at GPH over the out-of-sample period. The results of the study reveal that dog bite cases may slightly rise over the out-of-sample period. The study, amongst other policy directions, recommends Mass Dog Vaccination (MDV) as well as educating people about dogs in the GPH catchment area in order to reduce the numbers of dog bites as well as the negative heath impacts of this preventable public health concern.

Keywords: Dog bites, ANN(12, 12, 1) model, Mass Dog Vaccination (MDV), Public health.

1.0 INTRODUCTION

Any dog can potentially bite (Caffrey *et al.*, 2019), despite the fact that dogs are a common and valued household pet in many countries around the world (Davies, 2000; Degeling & Rock, 2013; Schurer *et al.*, 2015). Dog bites can have an array of negative health impacts on human victims (Reese & Vertalka, 2020) and these include rabies, disfigurement, amputation, full or partial paralysis, fear of animals, death, post-traumatic stress, depression, sleep disturbances as well as phobias about dogs and other animals (Loukaitou-Sideris, 2006; Ji *et al.*, 2010; Boat, 2019). Domestic dogs are the main reservoir species of the rabies virus (RABV) and by far the most common transmitter of the disease to humans (Hampson *et al.*, 2015). Worldwide, domestic dogs cause over 99% of human rabies deaths each year (Ma *et al.*, 2020). Because most human rabies exposures result from dog bites and highly efficacious dog rabies vaccines are available, the disease in humans can be prevented through vaccination of its animal source (Mbilo *et al.*, 2019). Zimbabwe is a rabies-endemic country with an estimated 410 humans succumbing to the entirely preventable disease annually (Hampson *et al.*, 2015).
Predictive modelling of dog bites is paramount, especially when considering ways by which to reduce the health impacts of the problem. This paper, in line with the Global Strategic Plan to end human deaths from dog-mediated rabies by 2030, will use the Artificial Neural Networks (ANNs) to model and forecast dog bites recorded and managed at Gweru Provincial Hospital in the Midlands province of Zimbabwe. Above all, there is a lack of studies analyzing the trends of dog bites in the country, particulary from a predictive modelling point of view. This study will fill-up this dearth in knowledge.

2.0 1.1 OBJECTIVES OF THE STUDY

i. To assess new dog bite cases at GPH over the period January 2010 to December 2019.
ii. To predict dog bite cases for GPH over the period January 2020 to December 2021.
iii. To determine whether dog bite cases are increasing or decreasing for GPH over the out of sample period.

2.0 RELATED STUDIES

Tenzin *et al.* (2011) estimated dog bite incidence, identified risk factors for dog bites in humans and also estimated the human deaths from rabies from rabies endemic south Bhutan. A hospital-based questionnaire survey was conducted during 2009-2010 among dog bites victims who visited three hospitals in Bhutan for anti-rabies vaccine injection. The study basically established that the majority of the victims were bitten by stray dogs. Coetzer *et al.* (2019), in a Zimbabwean study, investigated the epidemiological aspects of the persistant transmission of rabies in Harare. The Bayesian Markov Chain Monte Carlo approach was used for data analysis. The paper established that it is important to maintain rabies vaccination coverage and public awareness in order to control and or eliminate rabies. In a recent study carried out in Thailand, Paso & Ngamjarus (2020) used time series analysis (Holt-Winter and Box-Jenkins methods) to forecast rabies in dogs in the country. The study found out that during the period 2013-2017 there was a significant increase in the number of rabid dogs in northeastern Thailand. The optimal model for forecasting rabies in dogs in Thailand was found to be the SARIMA $(1, 1, 0)(0, 1, 1)_{12}$. No similar study has been carried out in Zimbabwe. Therefore, this paper will be the first of its kind in the case of Zimbabwe and will go a long in aiding policy formulation with regards to dog bites, not only within the GPH catchment area but also in the whole country at large.

3.0 METHODOLOGY

The paper applied the Artificial Neural Network (ANN) approach in modeling and forecasting monthly dog bite cases at GPH. Following Fischer & Gopal (1994), whose argument is that no strict rules exist for the determination of the ANN structure; the study applies the popular ANN (12, 12, 1) model based on the hyperbolic tangent activation function.

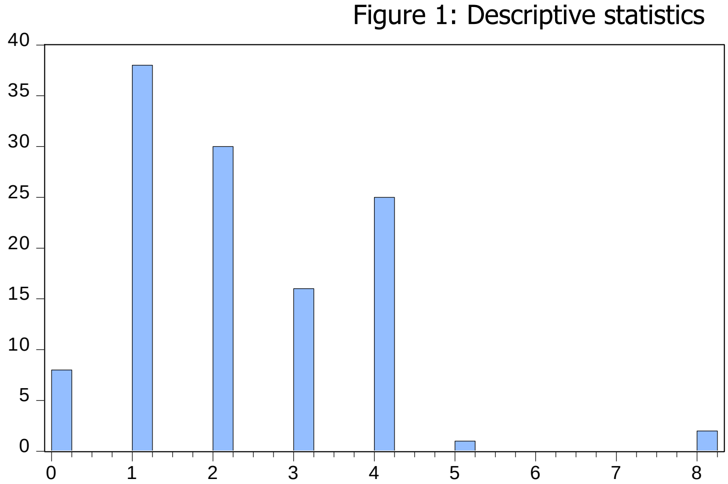
3.1 DATA ISSUES

This study is based on newly diagnosed monthly dog bite cases [for all age groups] (reffered to as DB series in this study) 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.

4.0 FINDINGS OF THE STUDY

4.1 DESCRIPTIVE STATISTICS

Figure 1: Descriptive statistics



Series: DB	
Sample 2010M01 2019M12	
Observations 120	
Mean	2.225000
Median	2.000000
Maximum	8.000000
Minimum	0.000000
Std. Dev.	1.480759
Skewness	1.027953
Kurtosis	4.969568
Jarque-Bera	40.52974
Probability	0.000000

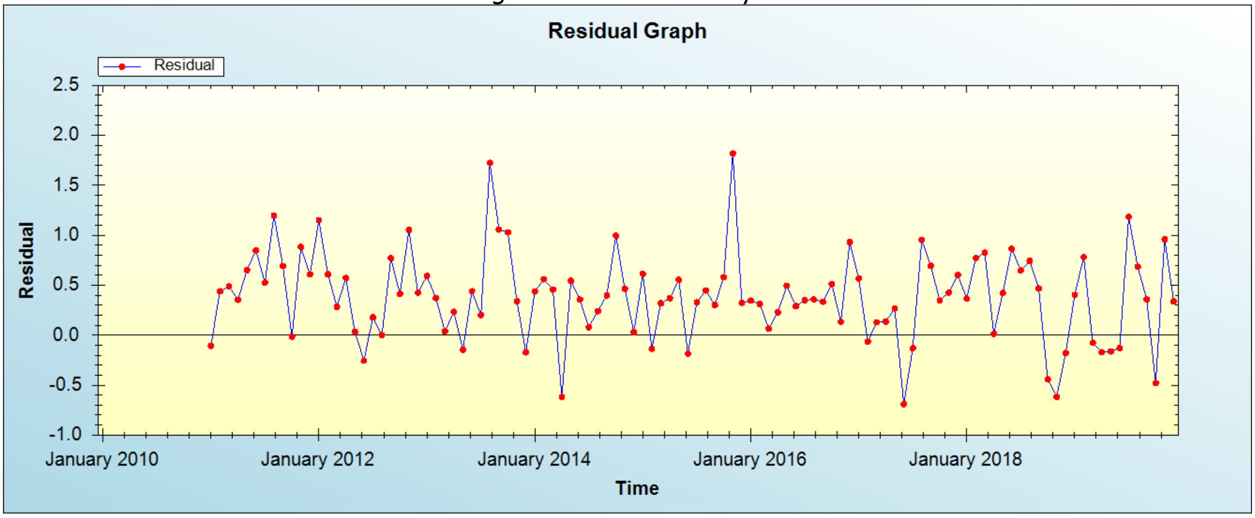
4.2 ANN Model Summary

Table 1: ANN model summary

Variable	DB
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	0.131363
MSE	0.340866
MAE	0.476913

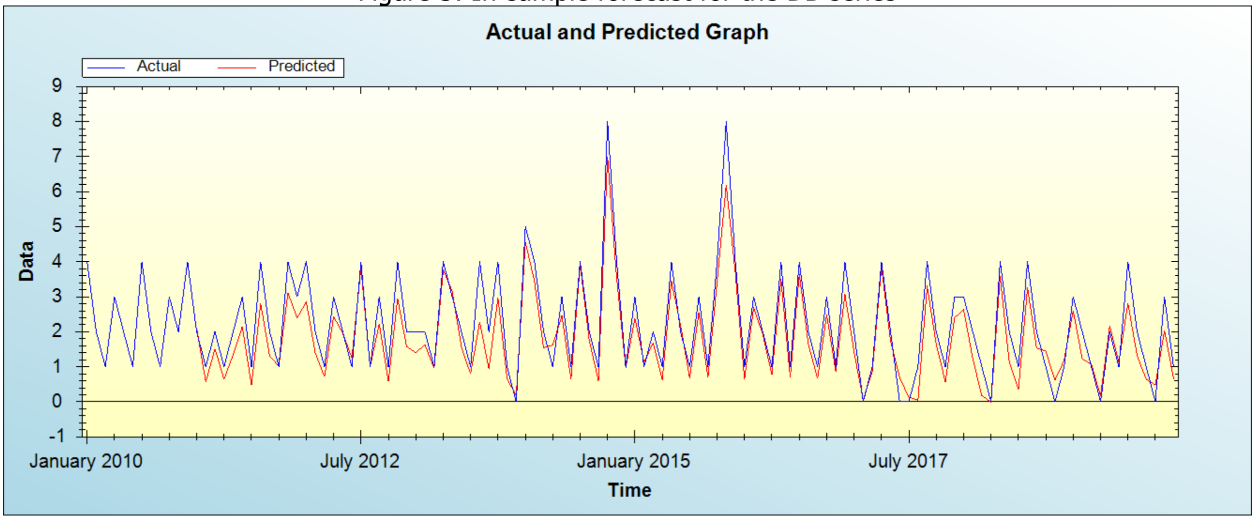
Residual Analysis for the Applied Model

Figure 2: Residual analysis



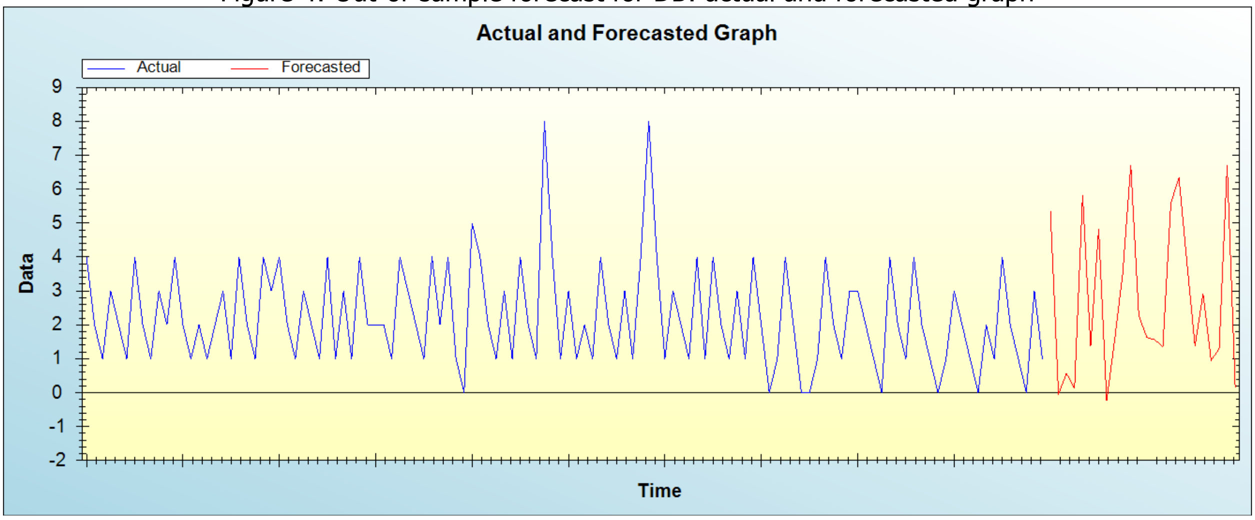
In-sample Forecast for DB

Figure 3: In-sample forecast for the DB series



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

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

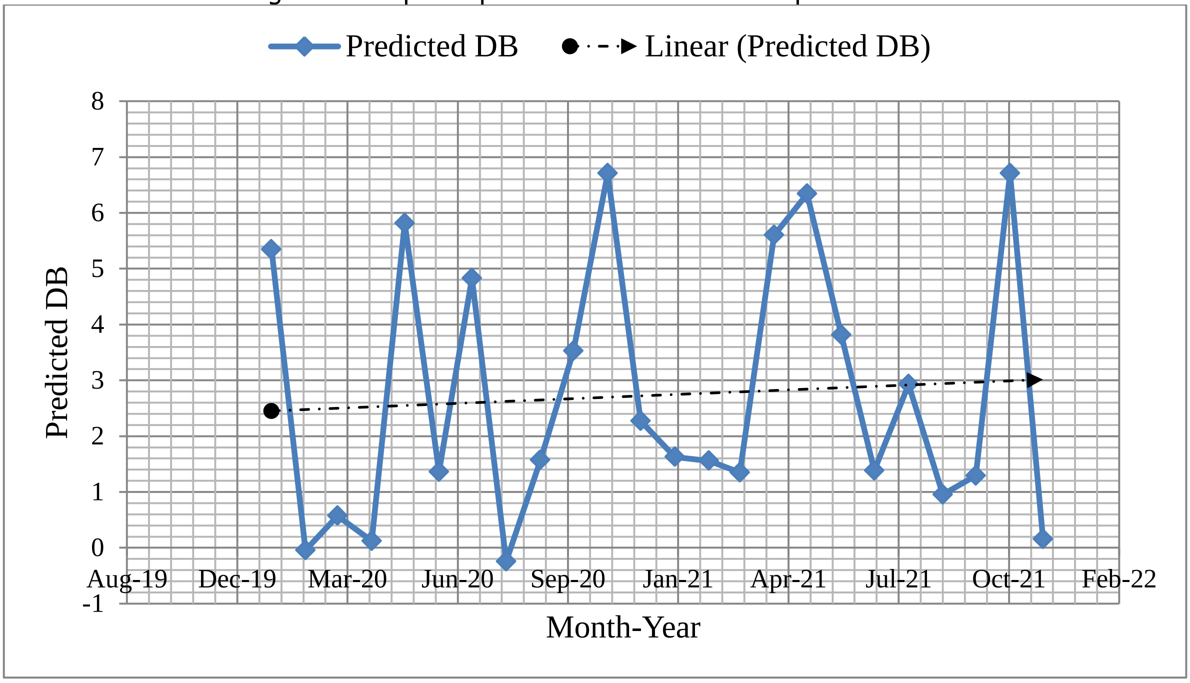


Out-of-Sample Forecast for DB: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Month/Year	Predicted DB
January 2020	5.3450
February 2020	-0.0450
March 2020	0.5722
April 2020	0.1207
May 2020	5.8167
June 2020	1.3609
July 2020	4.8283
August 2020	-0.2446
September 2020	1.5703
October 2020	3.5256
November 2020	6.7066
December 2020	2.2711
January 2021	1.6280
February 2021	1.5572
March 2021	1.3491
April 2021	5.6010
May 2021	6.3390
June 2021	3.8116
July 2021	1.3822
August 2021	2.9271
September 2021	0.9536
October 2021	1.2925
November 2021	6.7113
December 2021	0.1548

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



4.3 DISCUSSION OF THE RESULTS

Table 1 is the ANN model summary and basically shows the ANN (12, 12, 1) model, which has been based on the hyperbolic tangent function as its activation function. The "criteria" are the evaluation statistics and they all tell us that the model is adequate. Figure 2 shows the residuals of the model and because the residuals are as close to zero as possible, the model is deemed stable and acceptable for generating forecasts for dog bites cases at GPH. Figure 3 shows the in-sample forecast of the model and it is clear that the model fits well with data. Figure 4, table 2 and figure 5 are out of sample forecasts of DB. A striking feature of our forecast is that the dog bite cases may slightly rise over the out-of-sample period. Indeed, dog bites are a persistant public health concern (Ramgopal *et al.*, 2018) in the GPH catchment area.

5.0 CONCLUSION & RECOMMENDATIONS

This study basically demonstrated the importance of using an ANN (12, 12, 1) model to predict dog bite cases at GPH. The study used a monthly data set covering the period January 2010 to December 2019. The following recommendations are thus suggested:

i. There is need for Mass Dog Vaccination (MDV) in the GPH catchment area. The government, through the Ministry of Health and Childcare must play a pivotal role in MDV campaigns in the GPH catchment area.
ii. Following [i] above, the government of Zimbabwe should educate people in the GPH catchment area, (especially those who reside in rural areas), on how to assess body language of dogs, evaluate risk and take appropriate action. In this way, people will be able to prevent dog bites and the result health-related consequences.
iii. The GPH management team, with the support of community leaders; should increase disease awareness and ensure prompt Post-Exposure Prophylactic (PEP) treatment for dog bite victims. In this regard, emphasis should be placed on the importance of health-seeking behavior and prompt medication.

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