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Dr. Goutam Saha
Associate Professor, Department
of Statistics, M.B.B. College
Government of Tripura Agartala,
Tripura, India

Temporal trends and future projections of animal biting incidents: A comprehensive study from 2018 to 2023

Dr. Goutam Saha

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Abstract

Background: In India, high mortality and morbidity rates of human rabies is observed. Hence, a structured surveillance system is yet to be put in place for public health discussion.

Objective: The primary objective of this research study is to develop an accurate and reliable forecasting model for predicting the number of animal bites at the Territory Care Hospital located in Agartala, Tripura i.e., Agartala Government Medical College (AGMC) over the period June 2023 to May 2025. This endeavour aims to facilitate healthcare planning, resource allocation, and effective response to animal-related incidents, ultimately enhancing public health and safety in the region.

Methods and Materials: In this research, primary data have been collected from the Anti Rabies Vaccination (ARV) clinic of Agartala Government Medical College (AGMC), Agartala, Tripura West spanning April 2018 to May 2023 underwent rigorous cleaning, eliminating inconsistencies, duplicates, and outliers. The data was structured chronologically and organized by various regions in Tripura. For forecasting animal bites, a SARIMA (Seasonal Autoregressive Integrated Moving Average) model was meticulously tuned for optimal performance, considering parameters such as differencing order, autoregressive and moving average terms, and seasonal components. Model validation encompassed techniques like cross-validation, out-of-sample testing, and diagnostic checks. This holistic approach aims to provide a robust forecasting tool for predicting animal bites in different places of Tripura state over the period June 2023 to May 2025, thereby aiding healthcare planning and proactive measures to mitigate animal bite incidents in the region.

Results: This research paper employs time series analysis techniques to forecast animal bite incidents over the course of 24 months, spanning the period June 2023 to May 2025. The study establishes the stationarity of the time series data through the Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests, while confirming that residuals are normally distributed and independent. Utilizing the ARIMA function, the paper presents a robust forecasting model. The findings hold significance for animal control and public health, offering insights into expected trends and assisting in safety planning.

Keywords: SARIMA model, ADF and KPSS test, ARIMA function, stationery time series

Introduction

Dog bites globally result in tens of millions of injuries annually, with an estimated 4.5 million cases reported in the United States alone, leading to nearly 885,000 seeking medical care, 30,000 undergoing reconstructive procedures, and 10 to 20 fatalities. Comparable incidence and fatality rates are observed in other high-income countries like Australia, Canada, and France etc. ^[1]. This ongoing health crisis in India can be attributed to several interconnected factors. A fundamental issue is the lack of awareness regarding preventive p - measures against rabies, including post-exposure prophylaxis ^[2]. The Government of India's commitment to the National Rabies Control Programme aligns with the World Health Organization's (WHO) goal of eliminating human deaths from dog-mediated rabies worldwide by 2030. It recognizes that timely and appropriate interventions, coupled with high levels of awareness and vaccination coverage, are essential to achieving this ambitious target ^[3].

The application of Seasonal Autoregressive Integrated Moving Average (SARIMA) modelling to forecast animal bite incidents over the period June 2023 to May 2025 can be a valuable tool in fulfilling the target of rabies control and prevention set by the Government of India, as well

Corresponding Author:
Dr. Goutam Saha
Associate Professor, Department
of Statistics, M.B.B. College
Government of Tripura Agartala,
Tripura, India

as aligning with the World Health Organization's (WHO) goal of eliminating human deaths from animal mediated rabies by 2030^[4].

Here's how SARIMA can adequately contribute to achieving this target:

- **Data-Driven Decision-Making:** SARIMA models rely on historical data patterns and seasonality to make forecasts. By analyzing past animal bite incidents, the model can identify trends and seasonal variations. This information is crucial for decision-makers, allowing them to allocate resources and plan interventions strategically.
- **Resource Allocation:** Accurate forecasts generated by SARIMA can help authorities allocate resources effectively. For example, if the model predicts an upcoming surge in animal bite cases in a particular region, healthcare facilities can be prepared with an adequate supply of anti-rabies vaccines and immunoglobulin. This proactive approach can prevent shortages and ensure timely medical care for bite victims.
- **Targeted Awareness Campaigns:** SARIMA can provide insights into when and where animal bites are more likely to occur. This information can be used to target awareness campaigns in high-risk areas and during peak seasons, ensuring that communities are well-informed about rabies prevention and the importance of seeking medical care after a bite.
- **Monitoring Program Effectiveness:** As SARIMA continually updates its forecasts with new data; it can serve as a real-time monitoring tool. Decision-makers can track the impact of interventions, such as vaccination drives for both animals and humans, and adjust strategies accordingly.

- **Long-Term Planning:** The 24-month forecast horizon provided by SARIMA allows for long-term planning. This is particularly valuable for the National Rabies Control Program, as it enables the government to set goals, assess progress, and make necessary adjustments to ensure that the 2030 target of rabies elimination is met.
- **Resource Efficiency:** By predicting future animal bite incidents, SARIMA can help optimize resource allocation. This can reduce unnecessary costs and ensure that resources are directed where they are needed most, maximizing the impact of the National Rabies Control Program.

In summary, SARIMA modelling can be a powerful tool in fulfilling the target of rabies control and prevention in India. By providing accurate and timely forecasts of animal bite incidents, it empowers decision-makers to take proactive measures, allocate resources efficiently, and tailor interventions to high-risk areas and seasons. Ultimately, this data-driven approach contributes to the overarching goal of eliminating human deaths from dog-mediated rabies by 2030, as advocated by the WHO and the Government of India⁵.

Results

During last six years i.e. from April 2018 to May 2023 we have seen that there was total of 4246 cases reported in the Agartala Government Medical College (AGMC) and GBP Hospital, Agartala. A significant trend has been found from the data as, maximum bite cases are in the winter season and minimum in the summer (shown in Fig-2). The summary of data is as follows:

Table 1: The Summary of data

Minimum	1 st Quartile	Median	Mean	3 rd Quartile	Maximum
17.00	43.50	62.00	68.48	90.75	125.00

(Results computed by R software, version 4.3.1)

The dataset in Table-1 appears to have a wide range of animal bite counts, with a minimum of 17 and a maximum of 125. The majority of the observations (50%) fall around the median value of 62.00, suggesting that the typical number of animal bites during this period is around 62.

Whereas, the interquartile range (IQR), which is the difference between the 1st quartile (Q₁) and the 3rd quartile (Q₃), is fairly wide, indicating variability in the data distribution. The variance of the data set is 867.0407 suggests that there is moderate variability in the number of animal bites recorded during the specified period at Agartala Government Medical College. It's not extremely tightly clustered around the mean, but it's also not extremely spread out as variability do exist in real world data.

Box plot (fig-1) shows that there is no data outliers⁸. So, no need to take any other measures for removing outliers. And hence, in next we can proceed to the analysis i.e. forecasting. From the above figure-3 we observed that, lag 1 shows that, the previous data are more correlated with the current value where as lag 4, shows that worst cases i.e. less correlation between previous and current data.

The animal bite time series data graph i.e., decomposition graph was used for future analysis (fig-4). Firstly the series chart for observed data is shown in the figure.

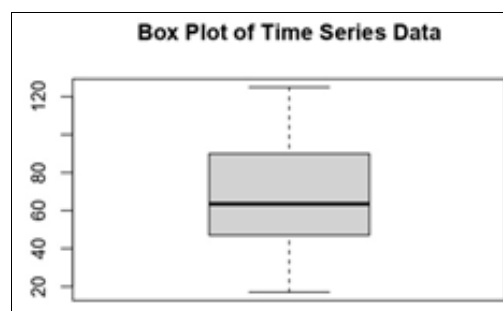


Fig 1: Box Plot of Time Series Data

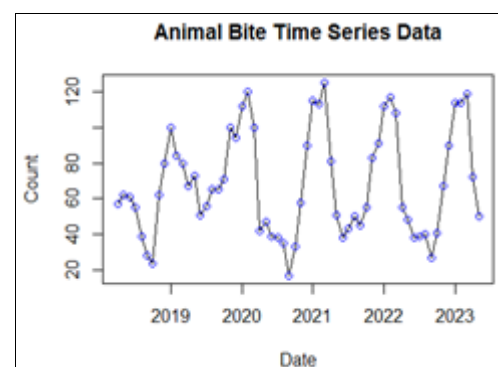


Fig 2: Animal Bite Time Series Data

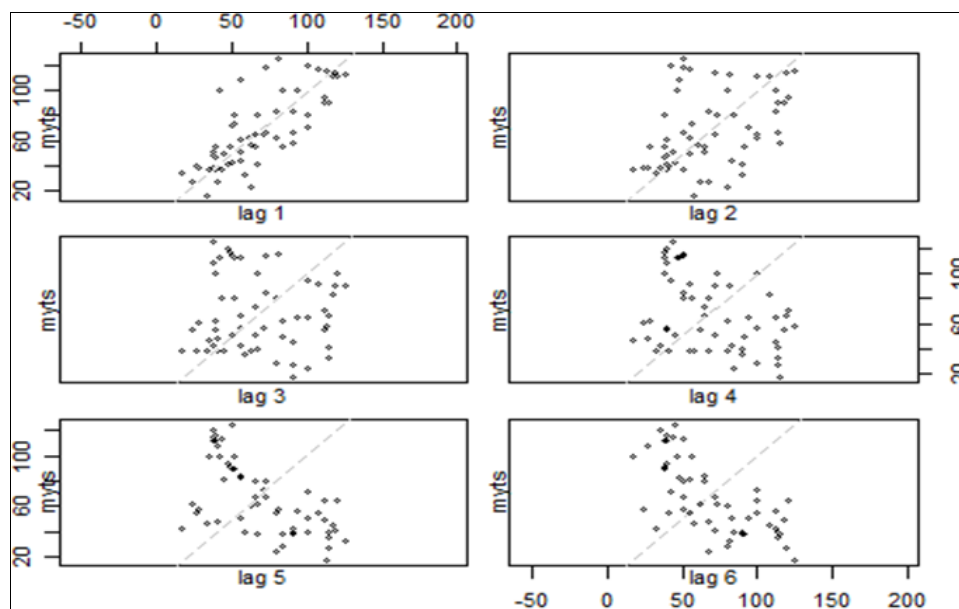


Fig 3: Correlation Analysis

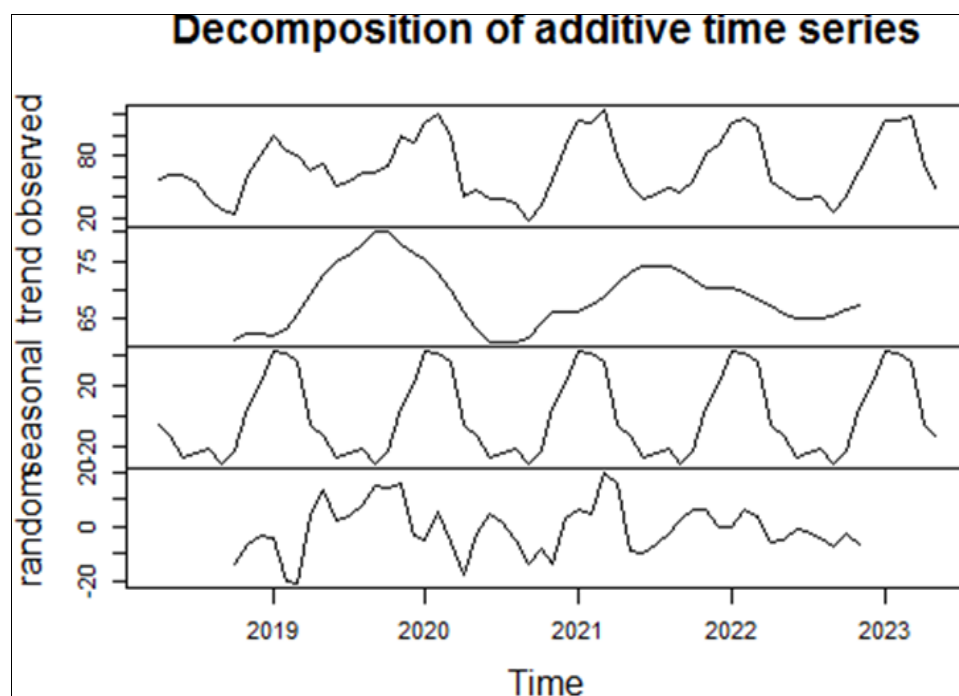


Fig 4: Decomposition Graph

Secondly trend was displayed, which climbed until the 2019 mid to very beginning of 2020 then started declining and again shows inclination from beginning of 2021 to very beginning of 2022 then started declining to ending of 2022. Thirdly shows the seasonal changes in the data of this series. And lastly shows the residuals of the time series after removing the trends and seasonal changes in the data, and it can be seen that this graph is not showing any particular pattern which ensures randomness of the data. ADF (P-value: 0.1, Decision: Fail to Reject Null (Stationary)) and KPSS (P-value: 0.1, Decision: Fail to Reject Null (Stationary)) test ensures that the data is stationary. Box L-jung test shows that (P value 0.4995, 20 df, 0.05 level of significance) residuals are free from autocorrelation i.e. data residuals are normally distributed and independent to each other.

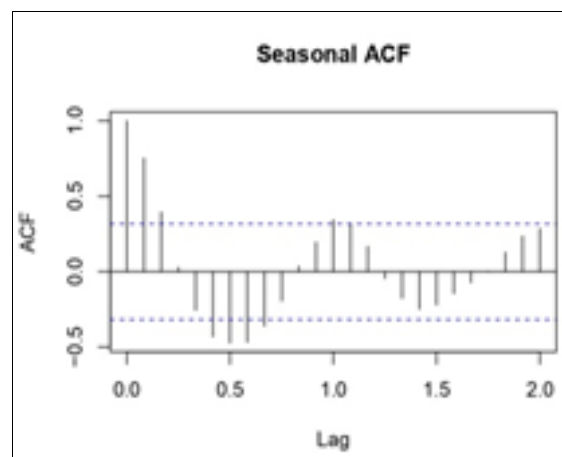


Fig 5: Seasonal ACF

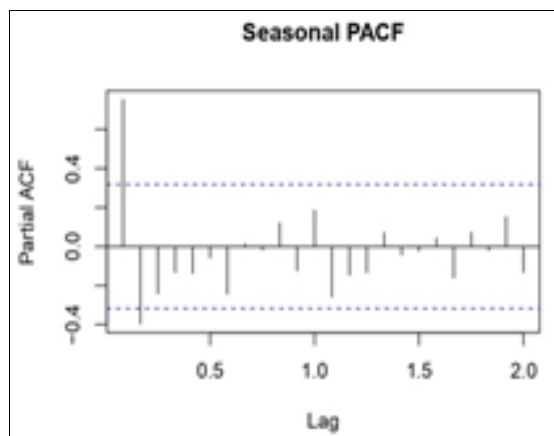


Fig 6: Seasonal PACF

ACF and PACF graphs were utilised to find out the seasonal p , d , q and non-seasonal P , D , Q of the model involved. Here from the PACF and ACF graph it has been shown that the non-seasonal MA value is $p=1$, differencing value $d=0$, and AR value $q=1$ and same for the Seasonal part $P=1$, $D=1$, $Q=0$

Table 3: Table of model residuals

Sigma square	Log likelihood	AIC	AICc	BIC	MAPE	MAE	MSE	RMSE
92.48	-187.5	382.99	383.88	390.64	9.22%	5.06	70.1	8.37

Here sigma squares represents the estimated variance of the model residuals or errors, the log likelihood measures how well the model explains the observed data, Lower values of AIC, AICc and BIC indicating a better-fitting model and hence these criteria balance the goodness of fit with the complexity of the model. MAPE shows the average percentage difference between the observed and predicted values. Lower MAPE indicates better accuracy, and 9.22% is generally considered reasonable, MAE shows the average absolute difference between the observed and predicted values, lower MAE shows better accuracy, MSE shows the average squared difference between observed and predicted values, lower MSE values indicating better accuracy, RMSE the square root of the MSE and provides a measure of the average magnitude of errors, lower RMSE value indicating better accuracy.

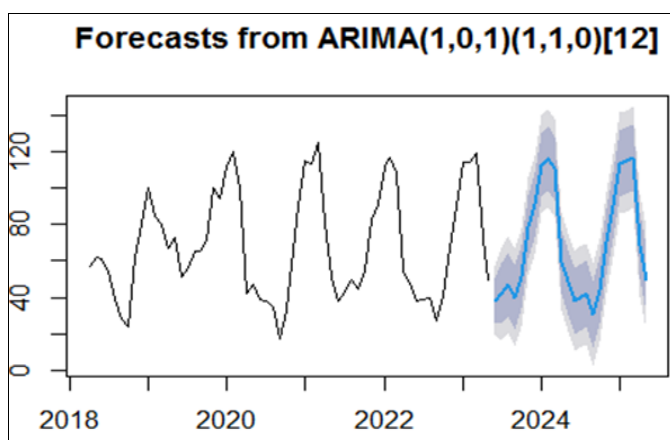


Fig 7: Forecast Graph from ARIMA

Here forecast graph i.e., Fig-7 shows that, maximum bites will occur in January, February, March of 2024 as well as 2025 and lowest number of bites will occur in June, July 2023, 2024 and in 2025 [9].

(SARIMA (p, d, q), (P, D, Q))^[10].

Accuracy matrices of the model involved are shown below:-

Table 2: Accuracy matrices model

AR1	MA1	SAR1
0.4842	0.4036	-0.7276
S.E = 0.1704	S.E = 0.1957	S.E = 0.0886

AR1 (0.4842) Indicates a tendency for the current month's value to follow the trend of the previous month. An increase in the previous month's value shows an increase in the current month's value. MA1 Coefficient (0.4036) implies that the current month's value is influenced by past forecast errors. An increase in past forecast errors is associated with an increase in the current month's value. SAR1 (-0.7276) reflects a seasonal effect. A higher value in the same month of the previous year is associated with a decrease in the current month's value. Lesser values of standard error ensure less uncertainty of coefficient estimates and better estimates of the coefficients.

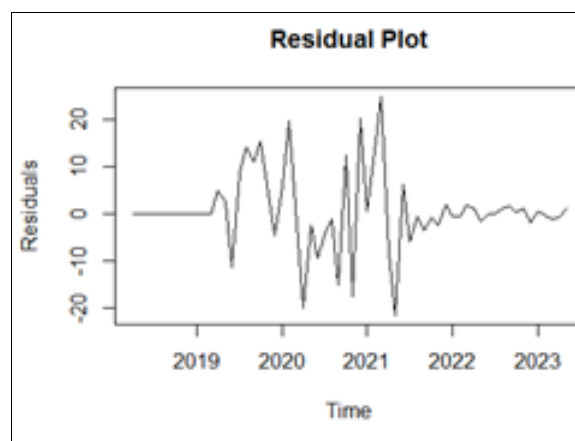


Fig 8: Residual Plot

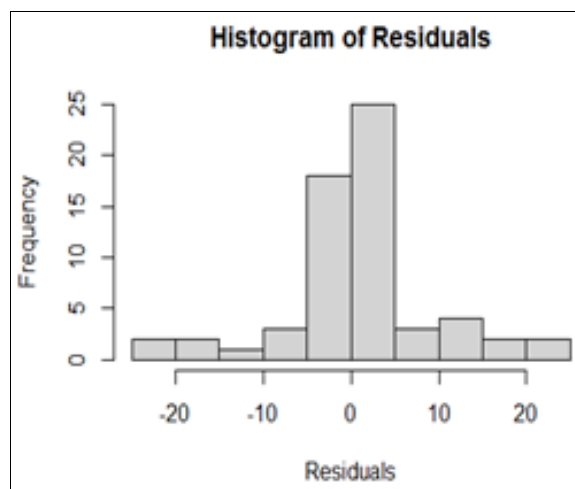


Fig 9: Histogram of Residuals

Residual plot shows that there is no particular pattern in the model error and considering this as only randomness. This is a sign of no autocorrelation among the residuals. Histogram

of the residuals shows that residual of the model tends to follow approximately normal distribution which also ensures randomness of the residual data and no particular pattern followed.

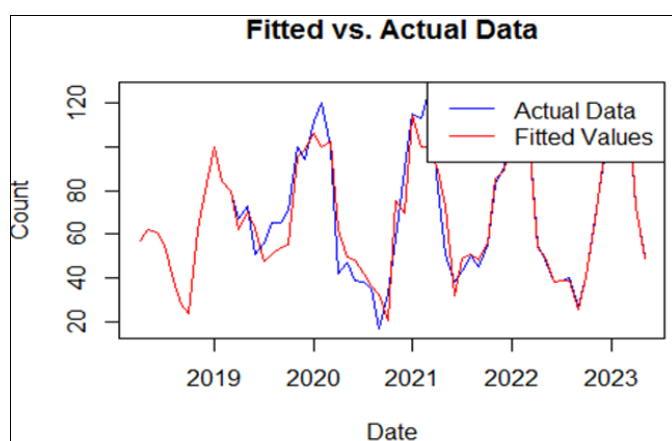


Fig 10: Graph of Actual Data Vs Fitted Data

Here Fig-10 show that lesser variation between two lines graph which ensures the goodness of fit of the model and more accurate results in terms of ARIMA modelling.

Conclusion

The analysis of animal bite cases at Agartala Government Medical College (AGMC) & GBP Hospital, Agartala, over the past six years reveals a seasonal trend, with peak occurrences in winter and minimal cases in summer. The ARIMA time series model, with identified parameters, provides a reasonable fit for forecasting. The forecast predicts higher cases in January, February, and March of 2024 and 2025, with lower numbers in June and July. Model evaluation matrices and residual analysis support the model's accuracy and randomness capture. This information can guide proactive planning and resource allocation for handling animal bite cases at the hospital.

Conflict of Interest

Not available

Financial Support

Not available

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