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Statistical Time Series Analysis on Malaria Cases among Children (0-5 Years) in Damaturu Town (A Case Study of Primary Health Care Centers, Damaturu, Yobe State, Nigeria)

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Abstract

This study applied statistical time series analysis to examine malaria cases among children aged 0–5 years in Primary Health Care (PHC) centers in Damaturu, Yobe State, using monthly data from 2017 to 2024. The study aimed to describe malaria patterns, examine long-term trends, identify seasonal components, fit an appropriate Seasonal Autoregressive Integrated Moving Average (SARIMA) model, and forecast future malaria incidence. Descriptive analysis showed a sharp increase in cases from 3,503 in 2017 to 25,412 in 2024, with a total of 109,101 cases recorded during the study period. Seasonal decomposition revealed consistent peaks during the rainy months of August to October, with October recording the highest transmission levels. Stationarity was confirmed using the Augmented Dickey–Fuller test ($p = 0.01$). Model identification based on ACF, PACF, AIC, and BIC criteria selected SARIMA(2,0,0)(0,1,1)[12] with drift as the best-fitting model. Forecasts for 2025–2026 indicated continued increases in malaria incidence, with projected peaks exceeding 3,700 and 3,900 cases, respectively. The findings confirm a significant upward trend and strong seasonal variation in malaria incidence among children under five in Damaturu. This study concludes that malaria remains a persistent and increasing public health challenge in the study area. The findings contribute to public health surveillance and epidemiological forecasting by demonstrating the value of SARIMA-based modelling for anticipating seasonal malaria burden. Practical implications include the need to strengthen seasonal interventions, improve surveillance, enhance resource allocation, and adopt predictive modelling for timely malaria control. Future research should incorporate climatic and socio-behavioral variables to improve forecast accuracy.

Keywords: Childhood Malaria; Damaturu; Primary Health Care; SARIMA Modelling; Time Series Analysis

INTRODUCTION

Malaria is one of the world's most severe public health problems and remains a leading cause of morbidity and mortality in many developing countries, especially in sub-Saharan Africa. Despite global progress in reducing the burden of malaria over the last two decades, the disease continues to show enormous health, social, and economic costs. According to the World Health Organization (WHO, 2023), there were an estimated 249 million cases of malaria globally, with about 608,000 deaths. Of these deaths, about 80% occurred among children under the age of five, making malaria the single most significant killer of young children in Africa. The term malaria was derived from two Latin words Mal means "bad" and Aria means "air", originating from the ancient misconception that the disease was caused by foul air in swampy and marshy areas.

Nigeria bears the largest global burden of malaria, accounting for about 27% of global malaria cases and 31% of global malaria deaths. The disease remains a major cause of outpatient consultations, hospital admissions, and deaths in the country. Yobe State, located in the northeastern region of Nigeria, has consistently reported high cases of malaria, worsened by factors such as seasonal rainfall, poor sanitation, widespread poverty, internally displaced populations due to insurgency, and limited access to health services. Children aged 0–5 years are the most vulnerable group because their immune systems are not yet fully developed. Malaria in this group is associated with severe anemia, cerebral complications, developmental delays, and high mortality rates. It is estimated that in Nigeria, a child dies from malaria every two minutes. In Damaturu, the state capital of Yobe, Primary Health Care (PHC) centers report malaria as the leading cause of consultations and childhood deaths. Despite several interventions, distribution of insecticide-treated nets (ITNs), indoor residual spraying (IRS), seasonal malaria chemoprevention (SMC), and improved access to antimalarial drugs, the prevalence remains significantly high.

Malaria is a tropical parasitic disease caused primarily by *Plasmodium falciparum* and transmitted by the bite of an infected female Anopheles mosquito. The mosquito pierces the skin with its proboscis to feed on human blood, simultaneously depositing the parasite into the bloodstream. The parasites first migrate to the liver, where they multiply, before invading red blood cells. This leads to the release of toxins into the bloodstream, which causes symptoms such as fever, chills, headache, vomiting, and flu-like signs. Symptoms typically appear within 9–14 days after infection. In cases where the parasites are drug-resistant, the infection may result in severe anemia, destruction of red blood cells, and blockage of blood vessels in the brain, which can progress to cerebral malaria.

Statement of the Problem

Despite efforts by individuals, governments, and non-governmental organizations (NGOs) to fight malaria, it continues to be a major public health challenges in Nigeria and globally. Its symptoms often resemble those of other diseases such as Dengue fever, which increases the difficulty of diagnosis, particularly in Asia and Africa. In Nigeria, malaria remains a significant threat to both children and adults, contributing to morbidity and mortality. If this knowledge gap is not addressed, malaria will continue to cause avoidable suffering, hospital strain, and child deaths in Damaturu. This study is designed to apply statistical time series analysis to malaria cases among children aged 0–5 years in PHC centers in Damaturu, with the aim of identifying patterns, modeling the data, and generating forecasts that can inform policy.

Objectives of the Research

The main objective of this research is to carry out a Statistical Time Series Analysis of Malaria Cases among Children aged (0-5 Years) in Primary Health Care Centers, Damaturu. Specifically, with the aim of achieving the following objectives;

1. To describe the pattern of malaria cases using simple descriptive measures.
2. To examine the historical trend of malaria cases among children aged 0–5 years in PHC centers in Damaturu.
3. To decompose the malaria cases time series into trend and seasonal components.

4. To estimate and validate the appropriate time series model to the malaria data
5. To fit appropriate statistical time series models to the malaria data for children under five.
6. To forecast future malaria incidences among children aged (0 - 5 Years) with the fitted model in order to assist health planning and interventions.
7. To provide recommendations for malaria prevention and control strategies based on statistical evidence.

Research Questions

1. What are the demographic determinants of malaria in the study area?
2. What is the historical trend of reported malaria cases between 2017 and 2024?
3. What is the reported number of malaria cases in the study area?
4. What forecasts can be generated for malaria cases in subsequent years?

Hypotheses

- **Null Hypothesis (H_O):** There is no significant trend or seasonal variation in malaria cases among children aged (0-5 Years) in Damaturu.
- **Alternative Hypothesis (H_1):** There is a significant trend and seasonal variation in malaria cases among children aged (0-5 Years) in Damaturu.

Scope of the Study

This study focuses on malaria cases recorded among children aged (0-5 Years) in Government Primary Health Care Centers in Damaturu Local Government, Yobe State. The data covered a period of 8 Years (2017 to 2024). The study employs statistical time series analysis, including trend analysis, seasonal decomposition, model fitting (e.g., ARIMA), and forecasting. It excludes other age groups, other diseases, and malaria data outside PHC centers.

Limitation of the Study

- Data Quality: The study relies on hospital records, which may contain errors, missing entries, or inconsistencies.

• Focus on Statistics: The study is restricted to statistical analysis and does not explore other biological, environmental, or socio-economic determinants of malaria transmission.

• Time Constraints: The study may be limited by the time available for data collection, analysis, and interpretation.

Significance of the Study

This study is significant for several reasons some of which are outlined below;

• **Public Health Importance:** The study addresses malaria in children, the most vulnerable age group, thereby contributing to efforts aimed at reducing childhood morbidity and mortality.

• **Policy and Planning:** Forecasts derived from the analysis will help government health agencies, NGOs, and international partners allocate resources more effectively and plan targeted interventions.

• **Scientific Contribution:** The study contributes to the body of knowledge by applying statistical time series modeling to malaria data in Damaturu, filling a gap in existing literature.

• **Early Warning Systems:** The results may serve as a early warning systems for malaria outbreaks in Yobe State.

Definition of Terms

Malaria: A parasite disease transmitted through the bite of infected female Anopheles mosquitoes, characterized by fever, chills, and other symptoms.

Time Series Analysis: A statistical method used to analyze data points collected or recorded at successive time intervals to identify trends, patterns, and forecast future values.

Trend: The long-term increase or decrease in malaria cases over time.

Seasonality: Predictable and recurrent patterns in malaria incidence associated with specific times of the year, such as rainy seasons.

Forecasting: The process of predicting future values of a time series based on historical data.

Primary Health Care Centers (PHCs): Government-supported health facilities that provide essential health services at the grassroots level.

Children (0 - 5 Years): A demographic group representing infants and young children whose immune systems are underdeveloped, making them highly vulnerable to malaria.

METHODOLOGY

The methods and procedures employed in conducting the study were described. It describes the study area to facilitate discussion of results which include; the location, the research design, population of study, data sources, method of data collection and analytical techniques. The methodology was carefully chosen to ensure that the study objectives are achieved in a valid, reliable, and scientific manner.

Study Area

The study is conducted in Damaturu, the capital of Yobe State in northeastern Nigeria sharing boundaries with Borno State and Bauchi State. Damaturu lies within the semi-arid Sahel region, characterized by seasonal rainfall and high temperatures that influence mosquito breeding patterns. The town has several Primary Health Care (PHC) centers, which serve as the first point of contact for the majority of the population. These centers maintain medical records of reported malaria cases, particularly among vulnerable groups such as children under five years.

Research Design

The study uses a quantitative research design, specifically a time series analytical design. This design is appropriate because the research aims to examine malaria cases among children aged (0-5 Years) across a period of time in Damaturu PHC Centers, secondary data obtained from PHC Centers records will be analyzed to identify patterns such as trends and seasonality, and forecast future values. Unlike cross-sectional studies that provide only a snapshot of data, time series analysis allows for a longitudinal assessment of malaria incidence and its variations over time.

Population of the Study

The population of this study consists of all malaria cases among Children (0-5 Years) recorded in Primary Health Care (PHC) centers, Damaturu, between January 2017 and December 2024. Also, the population of interest for this study comprises of children aged 0–5 years who were diagnosed with malaria in Primary Health Care centers in Damaturu within the study period.

According to Hyndman and Athanasopoulos (2021), time series forecasting becomes more robust when based on longer historical datasets, as it minimizes the effect of random variations. The population is therefore not individuals per se, but rather all malaria cases among Children (0 – 5 Years) within the PHC Centers records.

Sample and Sampling Techniques

This study makes use of secondary data covering all reported malaria cases among children aged (0-5 Years) within the defined period (2017–2024). As such, a complete enumeration (census sampling) of available data is adopted, eliminating the need for sampling techniques.

Sources of Data

The study relies primarily on secondary data sources, which are records that already exist rather than being generated through surveys or interviews. The main source is Health Records which is Monthly records of malaria cases among children aged 0–5 years obtained from Primary Health Care centers in Damaturu.

Secondary data has advantages, including cost-effectiveness, historical depth, and reliability, since official institutions typically ensure some level of accuracy in their reporting. However, drawbacks include possible data gaps, inconsistencies in record-keeping, and under-reporting. For instance, insurgency-related disruptions in Yobe State like, during the Boko Haram insurgency in 2014–2016 may have affected hospital and other related health centers operations, leading to incomplete documentation.

Method of Data Collection

Data were collected through an official request made to the Damaturu Local Government PHC Department. Monthly records of malaria cases among children aged 0–5 years were extracted and compiled into a dataset suitable for time series analysis. Data cleaning procedures (such as checking for missing entries, inconsistencies, or outliers) were conducted before analysis.

Method of Data Analysis

The analysis of the data involves several statistical and time series techniques, including:

1. Descriptive Statistics: Computation of frequencies, percentages, and pie chart to provide an overview of malaria incidence among children. Visualization of malaria cases using line charts to show temporal patterns.

2. **Time Series Decomposition:** Separation of malaria incidence into trend and seasonal components.

3. Model Identification and Estimation: Application of Autoregressive Integrated Moving Average (ARIMA) models and/or Seasonal ARIMA (SARIMA) to capture both short-term and seasonal dynamics.

4. Diagnostic Checking: Residual analysis to check for autocorrelation, stationarity, and model adequacy using tools such as the Ljung–Box Q test and autocorrelation function (ACF) and partial autocorrelation function (PACF) plots.

5. Forecasting: Generation of short-term forecasts for malaria cases among children under five. Presentation of forecasts using graphs and confidence intervals.

All statistical analyses will be carried out using software packages such as R, Excel, Python, SPSS, or EViews, depending on availability.

Model Specification

The general time series model applied in this study is the Seasonal Autoregressive Integrated Moving Average (SARIMA) model expressed as:

$$Y_t = \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} + y_{t-12} - \emptyset_1 y_{t-13} - \emptyset_2 y_{t-14} + c + \varepsilon_t + \theta_1 \varepsilon_{t-12}$$

Where:

Y_t = Malaria cases at time.

c = Constant.

Φ_1 = Autoregressive parameters.

Φ_2 = Autoregressive parameters

θ_1 = Moving Average parameters.

ε_t = white noise error term.

For specification data, the SARIMA model will be specified as

SARIMA(p, d, q) x $(P, D, Q)_S$

Where

p, d, q = Non-seasonal autoregressive, differencing, and moving average orders

P, D, Q = Seasonal components

s = Length of the seasonal cycle

Validity and Reliability of Data

Since the data used in this study are obtained from official health records, reliability is ensured by relying on standardized reporting systems employed by the Primary Health Care centers. Data cleaning and cross-verification with Ministry of Health records further enhance the validity of the data given.

RESULTS

This section presented and analyzed the data collected on malaria cases among children aged 0-5 Year from all primary health care centers in Damaturu Town from 2017 to 2024. The analysis is carried out using statistical time series techniques to identify key time series components like: trend, seasonality, cycles, and irregular fluctuations and forecast future malaria incidence which provides forecasts for 2025–2026 based on past patterns. These projections are intended to help health authorities and policymakers plan resource allocation and prepare for future malaria burdens affecting young children. Both descriptive and inferential statistics are employed, and results are presented in tables, graphs, and statistical models for interpretation.

Table 1. Malaria Cases among Children (0–5 years) in Damaturu (2017–2024)

Month/ Years	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2017	90	158	258	103	288	286	171	260	1179	158	255	297
2018	257	182	179	137	106	525	532	674	1495	2173	1264	485
2019	922	896	941	708	517	832	605	1522	2505	3184	3089	1692
2020	1262	1119	855	994	726	763	1127	1214	1620	2148	1171	669
2021	774	781	835	650	610	780	467	1250	1472	2215	1153	747
2022	476	441	586	510	525	702	775	2157	2040	2156	1232	1290
2023	569	402	683	595	736	774	1294	1377	1968	3143	1676	3255
2024	948	1161	1484	1572	1232	1588	2298	3480	2919	4460	2513	1757

Source: Primary Health Care Centers, Damaturu

Table 2. Annual Malaria Cases among Children (0–5 years) in Damaturu

S/N	YEAR	TOTAL	PERCENTAGE
1.	2017	3503	3.21
2.	2018	8009	7.34
3.	2019	17413	15.96
4.	2020	13668	12.53
5.	2021	11734	10.74
6.	2022	12890	11.81
7.	2023	16472	15.10
8.	2024	25412	23.29

Source: Primary Health Care Centers, Damaturu

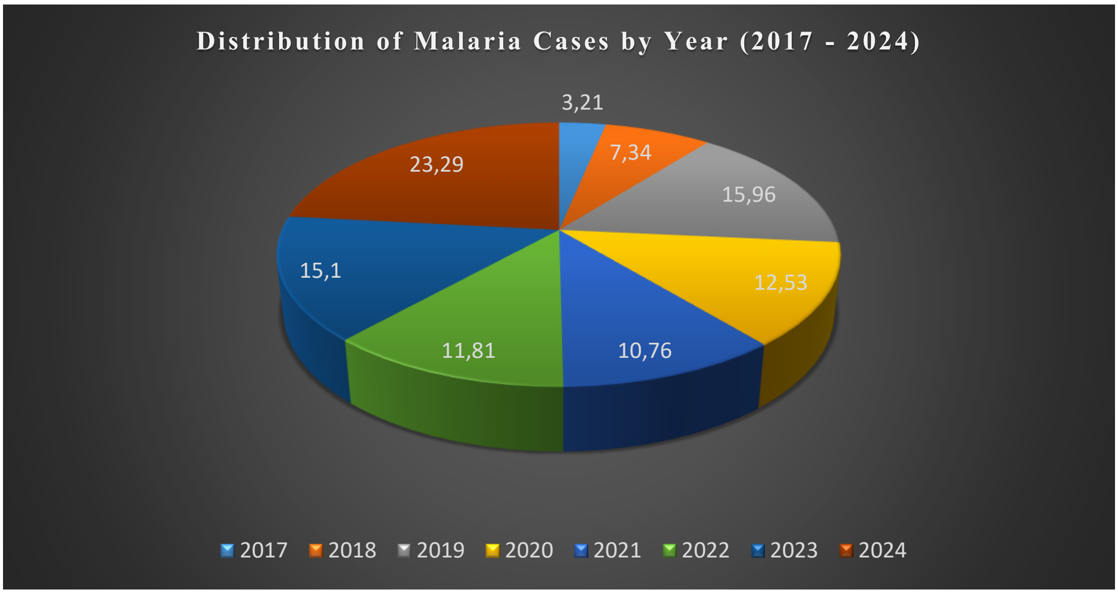

Figure 1. Pie chart of Annual percentages of Malaria Cases among Children

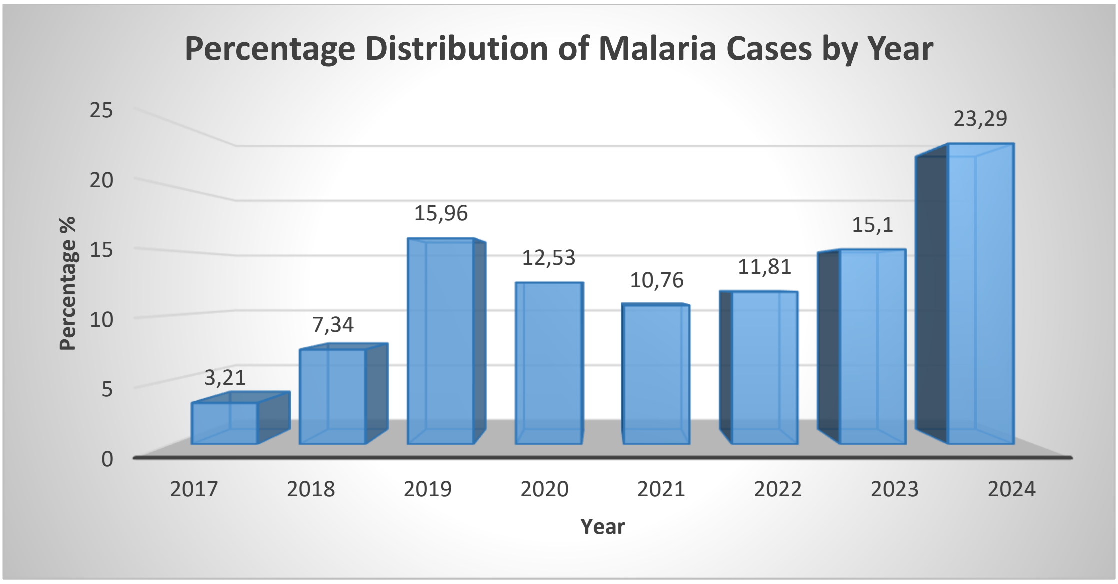

Figure 2. Bar chart of Annual Percentages of Malaria Cases among Children

Summary statistics

Mean	Median	SD	Min	Max	Total Cases
13638.	13279	6541.	3503	25412	109101

Summary statistics: This provides key statistical measures for the annual totals:

• **Mean:** The average number of cases per year (13,638).

• **Median:** The middle value of the annual cases (13,279), which helps understand the data's central tendency if there are extreme values.

• **SD (Standard Deviation):** A measure of how spread out the annual numbers are around the mean (~6,541). A high SD indicates high variability from year to year.

• **Min and Max:** The lowest (3,503 in 2017) and highest (25,412 in 2024) annual case counts.

• **Total Cases:** The sum of all cases over the 8-year period (109,101).

The descriptive analysis summarized annual malaria cases and their percentages (Table 2), alongside pie and bar chart visualizations. The results show a sharp increase in malaria cases over the years, rising from 3,503 cases in 2017 to 25,412 cases in 2024. The highest proportion of cases was recorded in 2024 (23.29%), while the lowest was in 2017 (3.21%). The overall total across the eight (8) years was 109,101 cases, with a mean of 13,638 and a median of 13,279.

Time Series Analysis

Trend of Malaria Cases

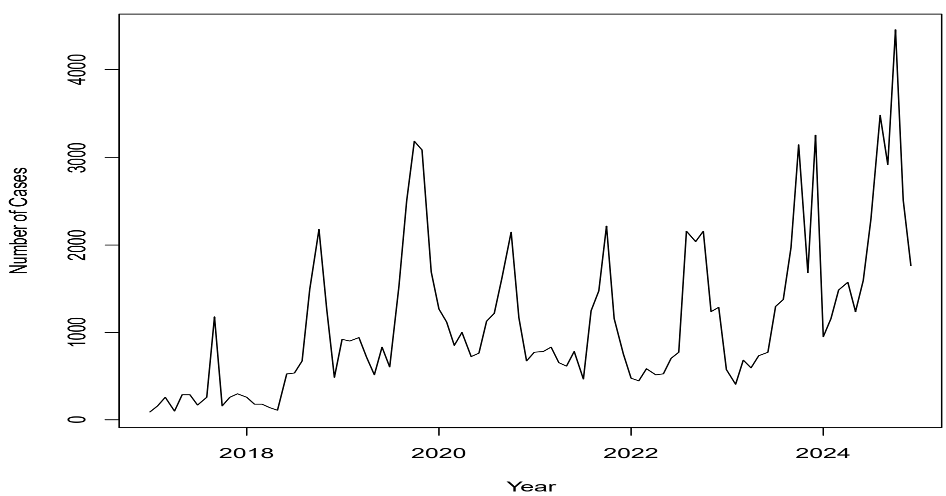

Figure 3. Trend of Malaria Cases in Children (0-5 Years) from 2017 - 2024

The trend analysis reveals a general upward movement in malaria cases over the eight years period. From relatively low figures in 2017 and 2018, there was a rise in 2019, followed by fluctuations in 2020–2022, and another rise in 2023–2024. This long-term trend indicates that malaria remains a growing public health concern in Damaturu. The upward trend suggests that interventions such as distribution of insecticide-treated nets (ITNs) and indoor residual spraying (IRS) may not have been sufficient in curbing malaria transmission.

Decomposition of Malaria Cases among Children (0-5 Years)

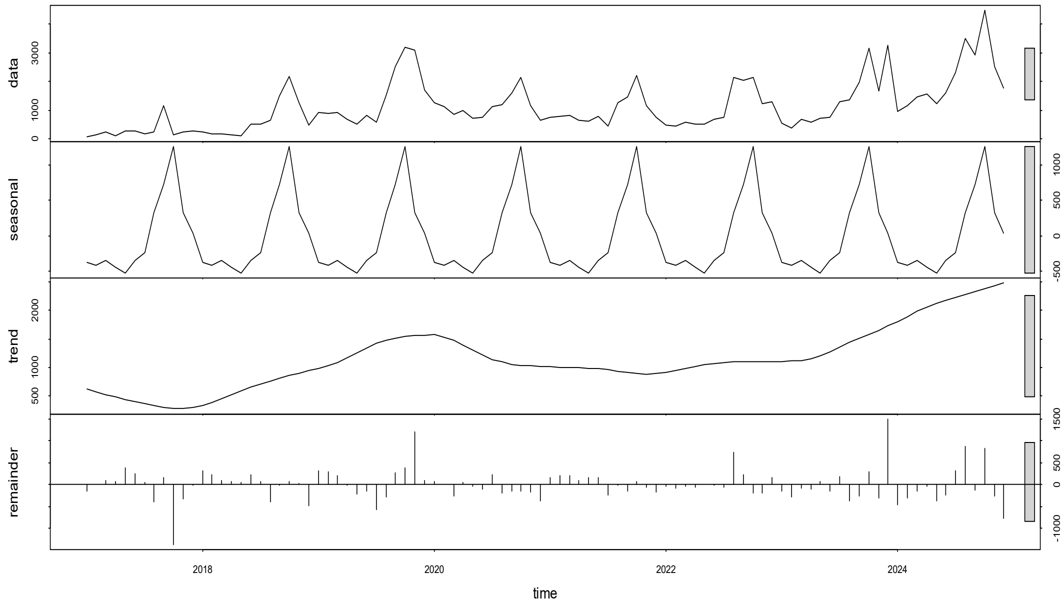

Figure 4. Time Series Decomposition of Malaria Cases

Stationarity test

Augmented Dickey-Fuller Test

Data: malaria cases among children

Dickey-Fuller = -4.1805, Lag order = 4, p-value = 0.01

Alternative hypothesis: stationary

The Augmented Dickey-Fuller (ADF) test yielded a test statistic of –4.1805 with a p-value of 0.01, which lead to the rejection of the null hypothesis that the data is stationary. In simple words, the test confirms that the data is stationary at the 5% significance level, meaning that it has a stable pattern over time that can be modeled effectively. Stationarity in time series modeling ensures that statistical properties such as mean and variance remain constant over time. The Implication is that the malaria case series is stable enough to be modeled with ARIMA, which strengthens the reliability of forecasts derived from the data. Without stationarity, any time series model would have produced misleading results.

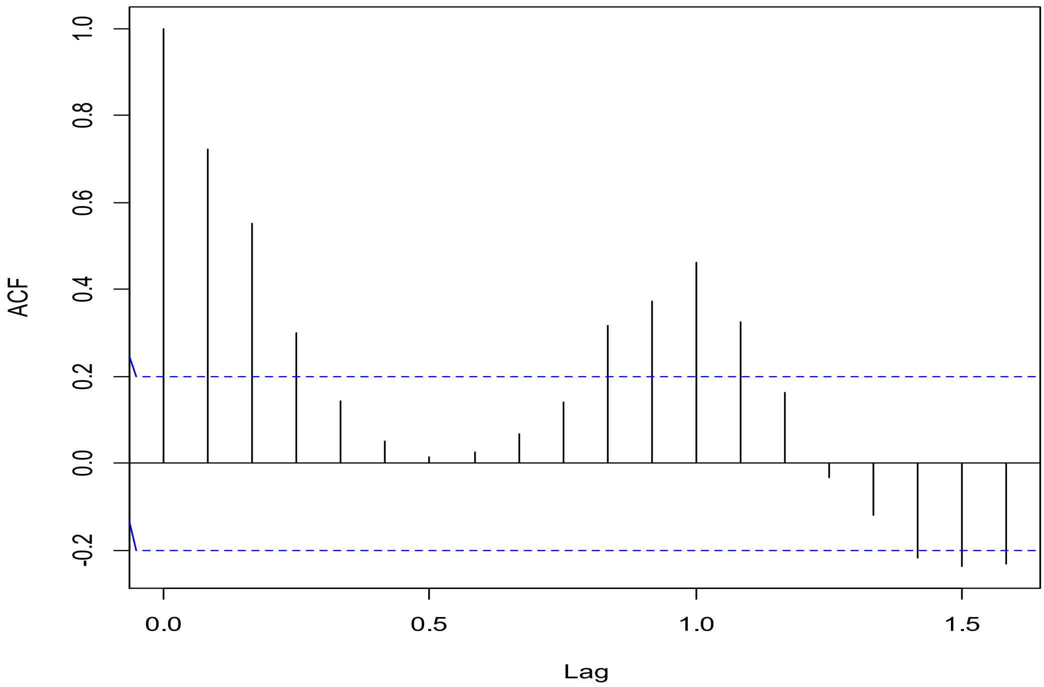

Figure 5. Autocorrelation Function (ACF) of Malaria Cases

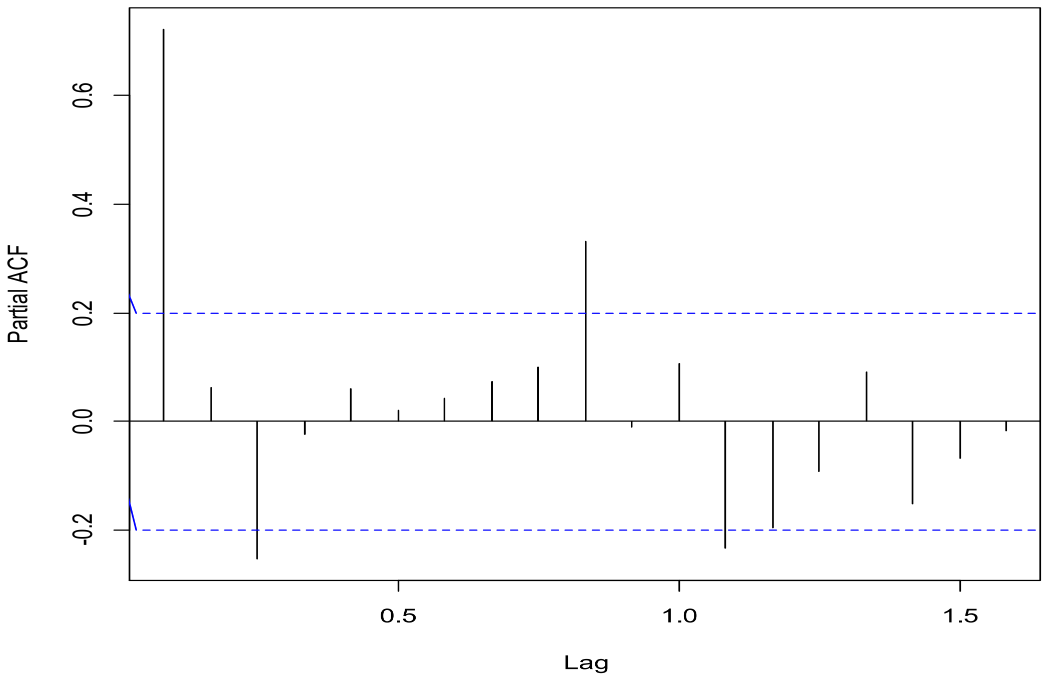

Figure 6. Partial Autocorrelation Function (PACF) of Malaria Cases

This step involves determining the most appropriate ARIMA/SARIMA model for the data. The ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function) plots are used to identify the parameters (p, d, q for non-seasonal and P, D, Q for seasonal components) that best capture the correlations within the data.

It led to the selection of an SARIMA(2,0,0)(0,1,1)[12] model with drift, which best captured the patterns in the data. This model accounts for both short-term correlations and seasonal variations in malaria cases. The Identified model shows the presence of both trend and seasonal components in the data. The seasonal parameter shows the annual cycle of malaria peaks, while the autoregressive parameters capture dependencies from past observations. This provides a strong foundation for forecasting future malaria cases in the study area.

Model Identification

To determine the best fitted model for the malaria cases, the Aikaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC) are calculated and compared for a set of tentative ARIMA models chosen based on the principle of parsimony and recognizable patterns of the ACF and PACF of the time series data.

Table 3. Tentative models of malaria cases with AIC and BIC values

Model	Non Seasonal (p,d,q)	Seasonal (P,D,Q)	AIC	BIC
1	(0,0,1)	(0,1,1)	1319.95	1327.242
2	(2,0,0)	(0,1,1)	1291.84	1303.99
3	(2,0,1)	(1,1,1)	1296.34	1310.925

In Table 3 Comparing the values of AIC and BIC we found that model 2 has the least value for both AIC and BIC which is considered as the most appropriate model for the malaria cases.

Table 4. Model diagnostic checking

Test	Q*	Df	p-value	Model df	Total lags used
Ljung Box	11.622	16	0.7696	3	19

Since p-value is greater than printed p-value, we fail to reject the null hypothesis and conclude that residual are white noise.

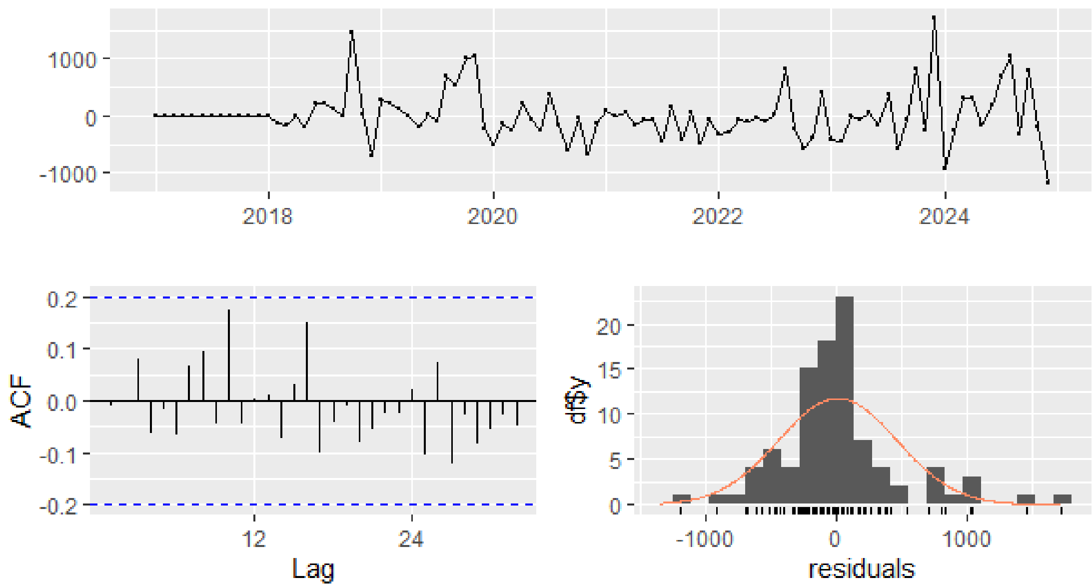

Figure 7. plot of residuals for the fitted model

Series: malaria cases among children

SARIMA(2,0,0)(0,1,1)[12] with drift

Coefficients:

	ar1	ar2	sma1	drift
	0.4351	0.2601	-0.6234	15.6854
s.e.	0.1131	0.1133	0.1303	6.8534

sigma^2 = 241503: log likelihood = -640.92

AIC=1291.84 AICc=1292.61 BIC=1303.99

Coefficients

• (ar1 = 0.4355): This means the value of malaria cases in the previous month has a positive and moderate influence on the current month's value. When last month increases, this month tends to increase too.

• (ar2 = 0.2601): This shows that malaria cases from two months ago still affect the current month.

• (sma1 = −0.6234): The negative value means that the seasonal shock from the same month last year influences the current month in the opposite direction. This confirms that malaria cases exhibit strong yearly (seasonal) patterns. Which is expected in diseases influenced by weather, rainfall, and mosquito cycles.

Model Evaluation

• ($sigma^2$ = 241503): This is the estimated variance of the residuals. A lower $sigma^2$ indicates a better fit. Given my large malaria counts, this number is reasonable.

• Log-Likelihood = −640.92: This shows how well the model fits the data. A higher (less negative) value indicates a better fit.

• AIC = 1291.84, AICc = 1292.61, BIC = 1303.99: Information criterion used to compare models.

Forecasting

FORECAST (2 Years)

Year	Month	Point_Forecast	Lo_80	Hi_80	Lo_95	Hi_95
2025	Jan	1141	511	1771	178	2104
2025	Feb	1074	388	1761	24	2125
2025	Mar	1358	615	2101	222	2494
2025	Apr	1348	580	2116	173	2522
2025	May	1257	473	2041	58	2456
2025	Jun	1482	689	2275	269	2695
2025	Jul	1877	1078	2676	656	3098
2025	Aug	2674	1872	3476	1448	3900
2025	Sep	2718	1914	3521	1488	3947
2025	Oct	3720	2915	4525	2489	4951
2025	Nov	2326	1521	3132	1094	3558
2025	Dec	2283	1477	3089	1050	3515
2026	Jan	1378	533	2224	85	2672
2026	Feb	1372	518	2226	66	2678
2026	Mar	1607	744	2469	288	2925
2026	Apr	1591	724	2457	266	2915
2026	May	1485	616	2354	156	2813
2026	Jun	1702	831	2572	371	3033
2026	Jul	2089	1218	2960	757	3421
2026	Aug	2881	2009	3753	1548	4214
2026	Sep	2920	2048	3792	1587	4254
2026	Oct	3919	3047	4791	2585	5253
2026	Nov	2523	1651	3395	1189	3857
2026	Dec	2478	1605	3350	1144	3812

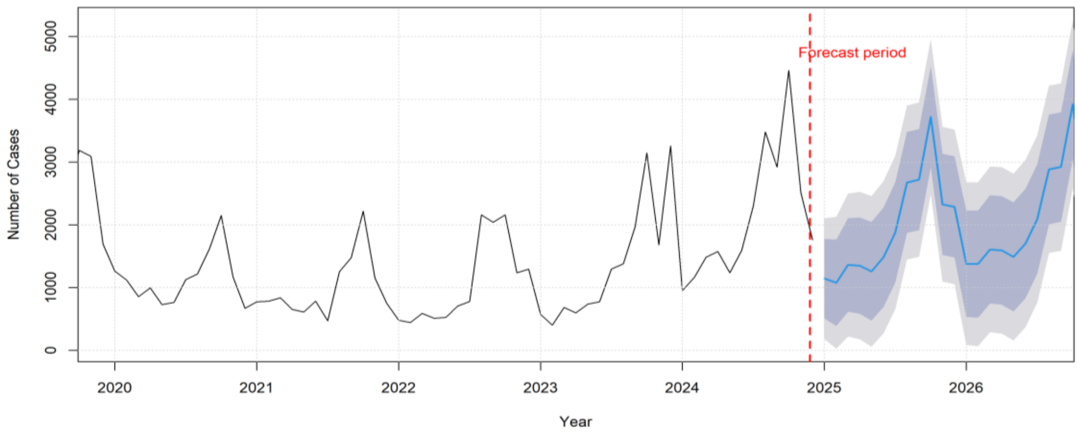

Figure 8. Trend Malaria Cases Forecast (2017-2026)

The SARIMA(2,0,0)(0,1,1)[12] with drift model was used to generate forecasts for malaria cases for the years 2025 and 2026. The results show that malaria cases will continue to rise, with peaks expected in the rainy months (August–October). For instance, October 2025 is forecasted at approximately 3,720 cases, while October 2026 is projected at 3,919 cases. Even during traditionally low months such as February and May, forecasts indicate cases will remain above 1,000.

• Forecast provides the actual predicted (Point Forecast) number of cases for each month in 2025 and 2026. It also provides prediction intervals (Lo_80/Hi_80 and Lo_95/Hi_95), which indicate the range within which future values are expected to fall with 80% and 95% confidence, respectively.

• Forecast plot is a graphical representation of the historical data, the model's fit, and the future forecasts with their confidence intervals. It allows for an easy visual assessment of the predicted trend and seasonality.

The forecasts provide critical insight into the predicted future courses of malaria in Damaturu. They suggest that malaria will remain endemic and that the disease cases may even worsen if no new interventions are introduced. The widening confidence intervals also highlight the uncertainty in long-term predictions, reinforcing the need for continuous surveillance and updated forecasting.

Hypothesis Testing

Null Hypothesis (H_0): There is no significant trend or seasonal variation in malaria cases among children aged 0–5 years in Damaturu.

Alternative Hypothesis (H_1): There is a significant trend and seasonal variation in malaria cases among children aged 0–5 years in Damaturu.

The Augmented Dickey–Fuller (ADF) test produced a test statistic of –4.18 with a p-value of 0.01. Since the p-value is less than the 5% significance level, the null hypothesis was rejected.

Conclusion: We reject H_o and conclude that there is strong statistical evidence of both trend and seasonal variation in malaria cases among children aged 0–5 years in Damaturu.

DISCUSSION

The results indicate that malaria cases among children have risen sharply over the study period, with the highest annual cases observed in 2024. This aligns with studies such as Akinboade et al. (2021) and Musa et al. (2020), which state climate factors like rainfall as significant drivers of malaria prevalence in Nigeria. The monthly/seasonal analysis further confirmed that peaks occur during the rainy season (August–October), which is consistent with the mosquito breeding cycle.

The SARIMA(2,0,0)(0,1,1)[12] model forecasts a continued rise in malaria incidence, with predicted peaks above 3,900 cases in October 2026. This shows the persistence of malaria transmission and possible worsening of the disease burden if current interventions are not taking.

Summary

This section presented and analyzed malaria cases among children aged 0–5 years in Damaturu between 2017 and 2024. Descriptive statistics revealed a steady rise in annual cases, from 3,503 in 2017 to 25,412 in 2024, with a total of 109,101 cases over the 8 years. Seasonal analysis showed peaks in the rainy months (August–October), particularly in October, while the ADF test and SARIMA modeling confirmed significant trend and seasonality.

The SARIMA-based forecasts for 2025–2026 suggest malaria cases will remain high, with further increases during rainy seasons. This chapter concludes that malaria remains a serious and growing public health challenge in Damaturu.

This section provides a summary of the entire research work, "Statistical Time Series Analysis of Malaria Cases among Children (0-5 Years) in Primary Health Care Centers, Damaturu, Yobe State." It shows the key findings from the data analysis presented in section three, and relate them back to the objectives and questions outlined in section One, and discusses their implications. It presents the conclusions drawn from these findings and offer a recommendation for policymakers, health planners, and future researchers. The aim is to translate the statistical evidence into actionable insights that can contribute to the reduction of the malaria burden in the study area.

The study successfully applied statistical time series analysis to eight years (2017–2024) of monthly malaria case data among children aged 0-5 years from Primary Health Care Centers in Damaturu. The primary objectives were to examine the historical trend, identify seasonal patterns, fit an appropriate time series model, forecast future incidence, and examine the cases using statistical tests.

The study utilized eight years (2017-2024) of monthly malaria case data obtained from official PHC records. The methodology involved descriptive statistics, time series decomposition, ARIMA/SARIMA modeling, and forecasting. The analysis confirmed a significant upward trend and strong seasonal variation in malaria cases. The analysis was guided by specific objectives, and the key findings are summarized as follows:

- **Historical Trend:** The analysis revealed an alarming upward trend in malaria cases over the eight-year period. The annual caseload increased dramatically from 3,503 cases in 2017 to 25,412 cases in 2024, representing a more than sevenfold increase. The total number of cases recorded over the period was 109,101. This persistent upward movement indicates a worsening malaria situation despite existing control efforts.

- **Model Fitting and Forecasting:** The time series data were found to be stationary, showing a key assumption for modeling. The most appropriate model identified was an S**ARIMA(2,0,0)(0,1,1)[12] model with drift**. This model effectively captured both the short-term autocorrelation and the strong seasonal component in the data. The model was used to forecast malaria cases for 2025 and 2026. The forecasts predict a continuation of the rising trend, with projected peaks exceeding 3,700 cases in October 2025 and 3,900 cases in October 2026. The forecasts also indicate that even the month with low-transmission have cases above 1,000.

• **Hypothesis Testing:** The **null hypothesis (H_0)**, which stated that there is no significant trend or seasonal variation, was **rejected**. The alternative hypothesis (H_1) was accepted, confirming the presence of both a significant upward trend and a strong seasonal pattern in malaria cases among children aged 0-5 years in Damaturu.

CONCLUSION

Based on the findings of this study, I, concluded that, Malaria remains a serious and escalating public health threat to children under five in Damaturu, with a significant upward trend in cases from 2017 to 2024. Transmission is highly seasonal, driven by climatic conditions that favor mosquito breeding during the rainy season, leading to predictable annual peaks. Also, the SARIMA model provides a reliable tool for forecasting future malaria cases, and its predictions suggest a growing burden that demands urgent attention.

The growth of malaria cases, despite control measures, suggest that these measures may be insufficient or facing challenges such as insecticide resistance. The findings outline the critical need for enhanced, evidence-based, and strategically timed interventions.

Recommendations

Based on the findings and conclusions of this study, the following recommendations are proposed for policy makers and Health Planners, Public health practice, and future researchers:

1. For Policy Makers and Health Planners:

• **Intensify Seasonal Interventions:** Resources for vector control (like, IRS) and chemoprevention (SMC) should be mobilized and deployed proactively before the peak rainy season (June-July) to mitigate the predictable surge in cases.

• **Resource Allocation and Preparedness:** Health authorities should use the forecasts from this study to anticipate drug, diagnostic, and logistical needs, especially during high-transmission months, to prevent stock-outs and ensure adequate care.

• **Strengthen Surveillance:** The Yobe State Ministry of Health should institutionalize routine time series analysis of malaria data as an early warning system to monitor trends and evaluate the impact of interventions dynamically.

2. For Public Health Practice:

• **Enhanced Vector Control:** Given the rising trend, there is a need to assess the effectiveness of current ITNs and IRS chemicals and explore complementary vector control strategies to address potential resistance.

• **Community Sensitization:** Public health campaigns should be intensified, focusing on environmental management (like, clearing stagnant water) and emphasizing early diagnosis and treatment, particularly in the months leading up to the peak season.

3. For Future Research:

• **Incorporate Covariates:** Future studies should integrate climatic data (rainfall, temperature, humidity) into the time series models to improve forecast accuracy and better quantify the environmental drivers of transmission.

• **Qualitative Component:** A mixed-methods study investigating the socio-behavioral and economic factors limiting the effectiveness of current interventions (like, ITN usage patterns, healthcare access barriers) would provide a deeper context for these statistical findings

Expanded Geographical Scope: Similar time series analyses should be conducted in other Local Government Areas of Yobe State to enable a comparative assessment and develop a state-wide strategic plan.

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