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MUKESH RANJAN

mukeshranjan311984@gmail.com

Pachhunga University College: Mizoram University Pachhunga University College

<https://orcid.org/0000-0002-5369-8081>

Sana Rafi

HNBGU: Hemvati Nandan Bahuguna Garhwal University

Mahendra Singh

HNB Garwal University: Hemvati Nandan Bahuguna Garhwal University

Ashutosh Singh

HNB Garwal University: Hemvati Nandan Bahuguna Garhwal University

Lalpawimawha -

Pachhunga University College: Mizoram University Pachhunga University College

R Zoramthanga

Pachhunga University College: Mizoram University Pachhunga University College

Vanlalhriatsaka -

Pachhunga University College: Mizoram University Pachhunga University College

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Temporal Dynamics of Malaria in Mizoram: A District wise Analysis

Mukesh Ranjan¹, Sana Rafi², Mahendra Singh², Ashutosh Singh^{2*}, Lalpawimawha¹, R. Zoramthanga¹, Vanlalhriatsaka¹

¹Department of Statistics, Pachhunga University College, Mizoram University, Aizawl, Mizoram.

²Department of Geography, Hemvati Nandan Bahuguna Garhwal University, SRT Campus, Badshahithaul, Tehri, Uttarakhand, India.

*Corresponding author email: ashutosh4shaurya@gmail.com

Abstract

India is the largest contributor of incidence of malaria cases and related deaths in southeast Asian region. The state of Mizoram is one of the significant contributors of Malaria cases in India. The present study focuses on the transition of malaria cases in the districts of Mizoram from 2011 to 2020. Various indicators including total malaria cases (TMC), Percent of *P. falciparum* (% Pf), Annual Parasite Index (API), Total positivity Rate (TPR), Annual Blood Examination Rate (ABER), and malarial deaths are processed through descriptive statistics, correlation and ANOVA to understand the disease epidemiology for Mizoram. Results revealed that Lawngtlai, Lunglei and Mamit districts are the top three in average number of malaria cases while Champhai recorded the lowest cases of malaria. Mamit recorded the highest number of malaria related deaths. Age group wise analysis showed that Malaria prevalence is highest in 15+ years of age, and the lowest is in 0-4 years of age. The malarial incidences were highest in the year 2015 for different age groups and sex. Correlation analysis results in significant correlation between TMC vs API, TMC vs TPR, API vs TPR in district Lawngtlai. District wise analysis of Malaria cases showed statistically significant difference ($p < 0.01$) between Lawngtlai and Mamit, Lawngtlai and Saiha, Lawngtlai and Serchhip, Lawngtlai and Serchhip. Findings of this study help in policy interventions and framework. State Vector Borne Diseases Control Programme (Malaria) Mizoram should increase intensified surveillance and monitoring of malaria cases, targeted vector control interventions, improved access to malaria diagnosis and treatments, community-based education and awareness programs.

Keywords: *Malaria, Mizoram, TPR, API, %pf, Total malaria cases, malarial deaths*

Introduction

In the South-East Asian region, malaria deaths have reduced by 74 percent from 35000 in 2000 to 9000 in 2019 [1]. However, for the past 3 years, the number of deaths has remained the same in

the region. Three countries accounted for 99.7 percent of the estimated malaria cases in the region, with India being the largest contributor (79%), followed by Indonesia (15%) and Myanmar (5%). While malaria deaths were accounted by India (57%), Indonesia (30%) and Myanmar (7%) respectively. *P. falciparum* was the dominant species in Bangladesh, India and Indonesia [1]. According to the previous world malaria report 2014, 22 percent (275.5m) of India's population lives in high transmission areas (>1 malaria case per 1000 population), 67 percent (838.9m) in low transmission area (0–1 case per 1000 population) and 11 percent (137.7m) in malaria-free areas (0 cases) [2]. In May 2015, World Health Assembly adopted the Global Technical Strategy (GTS) for malaria 2016 -2030 with attainable targets for 2030 (i) reducing malaria case incidences by at least 90%, (ii) reducing malaria mortality rates by at least 90%, (iii) eliminating malaria in at least 35 countries, (iv) preventing a resurgence of malaria in all malaria free countries [3]. As per WHO, 93% of the population in India are at the risk of malaria [3]. Malaria transmission is heterogenous across Indian landscape for its diverse ecology and multiplicity of disease vectors. In India, few States of the east, central and northeast contributes to 80% of total positive cases/ disease burden with concentration of cases (API >10). These states are associated with large forest cover, ethnic tribes, poverty and high rainfall [4]. In India, 61 species of anophelines have been found [5]. *Plasmodium falciparum* and *Plasmodium vivax* are the predominant infections [4]. Presently, 80% of the malaria cases occur among 20% of people classified as “high risk” while 82% of the country's population lives in malaria transmission risk areas. These populations at high-risk for malaria are found in 200 districts of Andhra Pradesh, Chhattisgarh, Gujarat, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Odisha, West Bengal and seven north-eastern states [3]. North-East (NE) Indian states along with Odisha, Chhattisgarh and Jharkhand contribute majority of the *P. falciparum* (Pf) cases in the country. NE India alone contributes to 12% of India's Pf cases and 15.2% of the TMCs by 2018 [6].

In India, it is estimated that 162.5 million people live in high-transmission areas, which includes many parts of the NE. The hilly and forested areas of NE India are mostly inhabited by the tribal population, and they are at the highest risk of malaria [7]. The distribution of *Plasmodium* species varies among NE states. Pf is the predominant species in Assam, Mizoram, Tripura and Meghalaya, while Pv is dominant in Nagaland, Arunachal Pradesh and Manipur. Apart from Pf and Pv, the other human malaria parasites, *P. ovale* and *P. malaria* have also been recorded from

Assam and Arunachal Pradesh [8,9,10] . The hot and humid climate aided by the numerous hill streams and its tributaries in these tribal areas support perennial mosquito breeding. Death due to malaria gradually decreased over the years. In India, 0.84 million malaria cases were reported in 2017, of which Northeastern (NE), Eastern and Central Indian regions contributed 80% of the total cases [7]. Mizoram along with Assam, Arunachal Pradesh, Tripura, Manipur, Mizoram, Sikkim and Meghalaya form the eight NE States of India. NE India accounts for 4% of the population but contributed 6.6% of malaria cases and 25% of malaria mortality in India in 2018 [11] . Multiple global climate models predict future climate to be more amenable for malaria transmission in the tropical highland regions. Malaria is the major vector-borne disease, and a serious public health concern in Mizoram. *Plasmodium falciparum* accounts for more than 90% of the malaria cases in Mizoram. This is the only state in the country where cases in 2019 (659 cases per 0.1 million population) have nearly doubled from 2018 (361 cases per 0.1 million population) [5]. During 2010–2018, the highest number of malaria incidences was recorded in Lawngtlai (36% of TMCs; 34.8 average API) while malaria cases in Champhai remained consistently low (0.4% of TMCs; 0.04 average API). Males of ≥ 15 years age contributed to 35.7%, maximum among gender and age malarial distribution during 2014–2018 [12]. During 2019 – 2020, the state has 8543 malaria cases [i.e., 6.98 API with ABER of 19.03] among these 8 died. Lawngtlai (44.25% cases), Lunglei (28.44% cases) and Mamit (22.28% cases) are the three highest case contributors among 9 districts in the state [13]. Malaria cases in Mizoram showed a declining trend from 2015 to 2018 and an increasing trend from 2019. Spatial variation is also seen, and the cases decreases from western district of Mamit to eastern districts of Champai because western districts more favorable in terms of temperature humidity and rainfall to facilitate the high endemicity of malaria cases [14]. Against this background, this study focuses on the epidemiological transition of Malaria and its dynamics in Mizoram from 2011 to 2020.

Study Area

Mizoram, a northeastern state in India, shares international borders with Myanmar and Bangladesh respectively and shares domestic borders with Manipur, Assam and Tripura. Mizoram's altitude ranges from 500-2157m, and the tropical humid climate of Mizoram is characterized by short and dry winters (part of November to February, 11–24 °C), and long summers (March to September, 18–33 °C). The monsoon season starts in May and extends till September, with 80% of rainfall

recorded in June to August. Mizoram receives 85 percent of its rainfall during the monsoon season (May-September) and vector borne diseases usually peak during the monsoon season. The tribal population of the State is 94.43% [5]. Mizoram's porous border with Myanmar is one of the major entry routes of drug-resistant parasites to mainland India. It is also considered to be one of the key routes through which drug-resistant parasites of Southeast Asia enter mainland India.

Data and Method

Month/year wise secondary data related to Malaria disease from 2010 to 2020 taken from the office of State Vector Disease Control Program (SVBDCP), Directorate of Health Services, Dintar, Aizawl Office, Mizoram has been used in this study. The data also has sex and age wise total number of malaria cases information for the different districts of Mizoram. The data was given in excel sheet in the form of tables which was converted into usable form datasheet (entered as variable name and cases) so that it can be easily exported to any software for the analysis purpose. Data analysis was done using STATA 13.1 software, and Microsoft Excel Worksheet (by activating 5g Data Analysis Tool pack Add ins).

1. Indicators Used

Several indicators traditionally used to monitor Total Malaria Cases (TMCs), Percent Pf (%Pf) cases, Annual Blood Examination Rate (ABER), Annual Parasite Index (API), Total positivity Rate (TPR) and deaths as captured under National Vector-borne Disease Control Program (NVDCP) and State Vector-borne Disease Control Program (SVDCP) were used. These indicators were selected for the study depending on their property to capture malaria epidemiology surveillance and malaria disease burden. Malaria epidemiological surveillance/case finding indicators as explained below:

(i) **Total numbers of malaria cases**: It is the total numbers of confirmed malaria cases as found in Blood Smear Examination (BSE) and Rapid Detection Test (RDT) as recorded annually for the period, 2010-2020.

(ii) **P. falciparum (Pf) Percentage (Pf %)**: It is the per cent of slides that are positive for P. falciparum. It indicates proportion of total malaria cases or total positive cases (which includes positive Pv and Pf cases). There are different types of malaria. Among those, Plasmodium falciparum malaria (pf) is the deadliest type of malaria. API though not true measures of

population prevalence or incidence do provide an approximation of disease burden in the population because presumably many who fall ill do come to PHCs or health facilities for treatment and thus have slides taken. Percent Pf cases should be a good measure of the relative occurrence of *falciparum* and non-*falciparum* malaria but provides no information on absolute occurrence.

It is calculated as $((\text{Pf positive cases}) / \text{total positive cases (Pf+Pv positive cases)}) * 100$

(iii) **Annual Parasite Index (API):** API is a measure of malaria morbidity for a given year at any given geographical level or it measures as the number of confirmed total positive cases (Pv+Pf positive cases) in the population of that geographical location as expressed per 1000 individuals under surveillance. The data is available for each district and Mizoram state for the period 2010-2020. API refers to high and moderate malaria transmission risk areas.

Calculated as $(\text{Total Positive Malaria cases} / \text{Population}) \times 1000$.

(vi) **Test Positivity Rate (TPR):** It is the proportion of total number of slides positive for malaria out of the Total Blood smear Examined per year. It is one of the useful indicators which highlights the positivity rate among those who come for testing in health facilities under both blood smear examination and Rapid Detection Test.

(iv) **Total deaths due to Malaria:** It is the total numbers of confirmed malaria deaths as recorded annually for the period, 2010-2020.

2. Statistical Techniques Used

Following techniques was applied in our study:

Descriptive Statistics: Since all our indicators are measured in ratio scale and hence are continuous, therefore Univariate Analysis (descriptive analysis) has been performed to provide the summary statistics of surveillance indicators (number of malaria cases, %pf) and malaria disease burden indicators (API, TPR and deaths) for different districts of Mizoram for the period 2010-2020. Measures of central tendency and dispersion (Mean, Median, Standard deviation, Kurtosis, Skewness and Range) were computed where mean indicates the average value of the variables of selected indicators. Medians tells the middle value of the variables which divides the data into two equal halves. Standard Deviation tells how much the value of the variable is deviated from our mean value. In the Kurtosis (Leptokurtic, Mesokurtic and Platykurtic) denotes whether the data peaked or not when compared to a normal distribution. Skewness tells whether the distribution is skewed or not based on the coefficient of skewness value. If the mean is larger than median and

mode, i.e, that data is positively skewed and vice versa. Range is simply the distance between the largest and smallest value of the variable present in our data.

Correlation, a bivariate analysis was performed to find the strength of relationship between two indicators. Its value lies between -1 to +1 through 0. Positive value indicates positive correlation (an increase in one variable leads to increase in other variables also) and negative value will indicate negative correlation (an increase in one variable leads to decrease in other variable) and strength will be indicated by its nearness to -1 or +1. If the indicators value is near to 1, it shows high degree of correlation (sign will decide positive or negative correlation) and nearness to 0 indicate lesser degree of relationship between the variables. Significance of correlation is also checked whether it is significantly different from zero in the population for these indicators (variables) involved or not. A significant correlation value between the two indicators is shown by star (*) sign showing that the correlation value is statistically significant at 5 percent level of significance in the population.

Box plots was used to create a visual summary of the distribution of different indicators to indicate the skewness (where the data is cluster; before or after the median), and the dispersion of indicators with respect to each district. The boxplot contains Interquartile Range (1st quartile, Median and 3rd quartile) and in both ends there is whiskers (the upper and lower adjacent values, which are the most extreme values). Box plots tell us about the outliers and what their values are. It also tells if our data is symmetrical, how tightly our data is grouped, and if and how our data is skewed. A boxplot is a graph that gives us a good indication of how the values in the data are spread out. Although boxplots may seem primitive in comparison to a histogram or density plot, they have advantage of taking up less space, which is useful when comparing distributions between many groups or datasets.

One Way ANOVA: which stands for analysis of variance, separates the overall variance in the outcome into variance explained by the group difference and the variance that is within each group (which is the variance unexplained by group). The test statistic F is the ratio of the variation in the outcome that is between groups divided by the amount within groups. Test statistic F, where MS group is the mean squared error of between group variance and MS error is the mean squared error of within group variance.

$$F = \text{MS group} / \text{MS error}$$

Assumptions:

- Random samples
- Independent observations
- The population of each group is normally distributed
- The population variances of all groups are equal.

A one-way (or single-factor) ANOVA can be run on a sample data to determine if the difference of mean of a response [continuous variable (i.e each of the surveillance indicators and disease burden indicators in our case)] is significantly different from zero or not for factor variable that is districts of Mizoram (categorical variable and has more than two category). It is whether to check if the mean of surveillance indicators says *API* for different districts of Mizoram (i.e., Aizawl East, Aizawl West, Kolasib, Mamit, Serchhip, Lunglei, Champhai, Saiha and Lawngtlai) differ significantly or not and if it differs then which pair of districts these differences are significant.

Hypothesis: (for k (here $k=9$) independent groups)

H_0 : The malaria disease surveillance/disease burden indicators mean for different districts of Mizoram are equal, or $\mu_1 = \mu_2 = \dots = \mu_9$

H_A : At least particular malaria disease surveillance/disease burden indicator means is different for a pair of districts, or $U_i \neq U_j$ for some i, j ($i \neq j$ and $i=1, 2, \dots, 9$ & $j=1, 2, \dots, 9$)

Degrees of Freedom: Between groups ($k-1=9-1$) = 8; Error (within groups) ($N-k$) = $11 \times 9 - 9 = 90$, where k is the number of district and N is the values of the indicator for 11 years for different districts.

Post-hoc Testing: If ANOVA results in a significant F-statistic, which indicates that there is some difference in means, it is common to investigate which pairs of groups have significantly different means. Post-hoc testing can accomplish this with pair wise comparison tests (independent t-tests). The number of possible pair wise comparisons is equal to $k(k-1)/2$. Due to an increased risk to type-1 errors (rejecting a true null hypothesis), when conducting multiple pair wise tests, it is recommended to use a correction, such as the Bonferroni correction, Fisher's least significant difference (LSD), or Tuekey's procedure. Here, Bonferroni correction is used to indicate the significant pair of districts where difference exist related to a particular indicator.

Results

From 2010-2020, malaria was persistent throughout the year and across all districts in the state of Mizoram (Fig 1- 9). 1,32,155 slides were tested positive of the total samples tested from 9 districts of Mizoram. Of the total positive cases, most malaria incidences were contributed by Lawngtlai (33.6 average API, 49,486 TMCs; 44,836 PF, 4690 PV); followed by Lunglei (242 average API, 40597 TMCs; 36749 PF, 3848 PV). The total of malaria cases (total malaria, %PF, API, TPR) throughout 11 years of study was estimated. The number of malaria related deaths was also observed. Maximum deaths were reported from Mamit (13). Distribution of age and gender-specific malarial infection, passive case detection is recorded. Overall 15+ years of age had the highest malaria incidence whereas 0-4 years of age had the lowest malaria incidence. Table 1 shows the descriptive statistics of the selected indicators. Lawngtlai, Lunglei and Mamit districts are the top three in total number of malaria cases (mean = 4498.7, 3690.6, 2365.5 respectively) while Champhai (53.8) recorded the lowest during 2010-2020. The percentage of Plasmodium falciparum(pf) cases is high in Mamit (92.5%), Lunglei (90.5%), Lawngtlai (90.3%) while Aizawl East (68.6%) has the lowest pf cases during the years 2010-2020. Table 1 also shows that Annual Parasite Index (API) are highest in the districts of Lawngtlai (33.6 per 1000), Mamit (30.7 per thousand) and Lunglei (24.2 per thousand) however Champhai (0.37 per thousand) has the lowest rate during the years 2010-2020. During the years 2010-2020; average death cases was observed as 3.3, 2.91 and 2.9 due to malaria in the respective districts of Lawngtlai, Mamit and Lunglei. White Champhai have the lowest average death cases (0.64 death).

District wise Correlations Analysis

Table 2 shows that in Aizawl East district, there is a significant positive correlation between TMC and API, TMC and TPR, API and TPR in Aizawl East, Aizawl West, Lawngtlai, Saiha, and Mamit districts. This mean that with increasing TMCs, API and TPR also increase and TPR also increases with an increase in API. Significant correlation is also found among TMC and API, TMC and TPR, TMC and Deaths, API and TPR, API and Deaths, and TPR and Deaths in Kolasib District. While in Champhai District, there is a significant correlation in between TMC and API, TMC and TPR, TMC and % Pf, API and TPR. Serchhip district also revealed a significant correlation in between TMC and API, TMC and TPR, Deaths and TPR. And in Lunglei district a significant correlation in between TMC and API, TMC and Deaths, API and Deaths was found.

District wise Indicators Analysis through Boxplot Visualization

Analysis shows that during the years 2010-2020 Aizawl East has the largest range of pf % among the 9 districts where it ranges between 96% at 2010 and 25.6% at 2017 and it is positively skewed while shortest being observed in Lunglei (Figure 11). Figure. 11 further shows that Mamit has the longest range for Annual Positivity Rate (API) from 109.8 per thousand in 2015 and 7.5 per thousand in 2020 with median being 21.05 per thousand and positively skewed. The range of Total Malaria Cases (TMC) was observed in Lunglei district (7745 people in 2015 and 1092 people in 2018) among 9 districts and is positively skewed while shortest range was observed in Champai (Figure 11). While the range of total deaths was observed in Aizawl west and Mamit and shortest is in Champai (Figure 11)

District wise ANOVA Analysis

Table 3 shows ANOVA tables for district wise comparison of indicators i.e API, %Pf, TMCs between 2010-2020. From the pairwise comparison of API cases, statistically significant ($p < 0.01$) difference was found between pairs of Aizawl East vs Lawngtlai, Aizawl East vs Lunglei, Aizawl East vs Mamit, when district Aizawl East was compared with other districts. Comparison of Aizawl west with other districts shows statistically significant difference between Aizawl West vs Lawngtlai, Aizawl West vs Lunglei, Aizawl West vs Mamit ($p < 0.01$). Mean API of district Champhai was found to be statistically significantly different from Lawngtlai, Lunglei, and Mamit ($p < 0.01$). While for Kolasib, statistically significant difference was found for Lawngtlai, Lunglei, and Mamit. Statistically significant difference was also found for Lawngtlai vs Saiha, Lawngtlai vs Serchhip, and for Mamit vs Saiha, and Mamit vs Serchhip at ($p < 0.01$). For the pair of districts Lunglei and Serchhip there is statistical high significant difference in terms of Mean API at 1% level of significant. From the pairwise comparison of % pf cases, statistically significantly high ($p < 0.01$) difference was found for Aizawl East with Lawngtlai, Lunglei, and Mamit. Mean API of district Aizawl West was found to be statistically significantly different from Lawngtlai, Lunglei, and Mamit ($p < 0.01$). There is also statistically significant difference between Champhai and Mamit at 1% level of significant.

From the pair wise comparison of Malaria cases, statistically significant ($p < 0.01$) difference was found between pairs of Aizawl East vs Lawngtlai, Aizawl East vs Lunglei, Aizawl East vs Mamit,

when district Aizawl East was compared with other districts and same is found for Aizawl West, and Champhai and districts. Statistically high significant difference also exists between Kolasib with Lawngtlai, Lunglei, and Mamit at 1% level of significance. Lawngtlai district is statistically different from Mamit, Saiha, Serchhip with high significance ($p=1$). Further, there is statistically highly significant difference lies between Lunglei and Saiha, Lunglei and Serchhip, and between Mamit and Saiha, Mamit and Serchhip in terms of Malaria cases ($p=1$).

Discussion

This study shows the prevalence of malaria in Mizoram from 2010 to 2020 using different statistical technique. From the graphical analysis, it is evident that during the years 2014-2015 the trend of malaria was high compared to other years in every district of Mizoram. From the descriptive statistics, TMC is highest in Lawngtlai followed by Lunglei and Mamit and lowest in Champhai. Lawngtlai, Lunglei and Mamit districts have a distinct high case compared to the other districts for almost every year. As the rate of blood examination is increasing, the number of positive cases (malaria pf cases) is also increasing every year. The percentage of Plasmodium falciparum is high in Mamit (92.5%), Lunglei (90.5%), Lawngtlai (90.3%) while is low in Aizawl East (68.6%) from 2010 to 2020 and the Annual Parasite Index (API) i.e; no. of positive case in each district per thousand population. Lawngtlai (33.6 per 1000), Mamit (30.7 per thousand) and Lunglei (24.2 per thousand) are the highest API rate districts of Mizoram and Champhai (0.37 per thousand) is having the lowest API rate on average during the years 2010-2020. The years 2010-2020; 3.3, 2.91 and 2.9 people died on average due to malaria in Lawngtlai, Mamit and Lunglei district. They have the highest death cases in Mizoram and Champhai have the lowest cases (0.64 death) in average. The Mosquitos need humidity around 20°C to 30°C to survive for longer period and that humidity period is the best time for Mosquitos to give birth and transmission of disease. According to the Meteorological data of Mizoram 2020, published by Directorate of Economics and Statistics, Government of Mizoram, three districts, Lawngtlai, Lunglei and Mamit districts got the highest rainfall over the other districts, and it can be one of the factors of abundant malaria cases in these three districts. According to a study on Malaria Prevalence in Mizoram, the districts of Lawngtlai, Mamit and Lunglei bear the highest burden of the Malaria [12]. While another study found that factors such as inadequate healthcare, poor Knowledge and awareness about Malaria, low socio-economic status, and climate change have been identified as a major contributor to the

high incidences of malaria in the northeast region of India[15]. The present study also corroborates the findings of earlier studies and it revealed that Malaria is causing the health burden for the districts of Lawngtlai, Mamit and Lunglei in Mizoram. These three districts have total forest area of 1896 km², 1904 km², and 2202 km² as per the India State of Forest Report, 2019, and according to the India Meteorological Department (IMD), the average temperature ranges from 12 °C to 31 °C in Lawngtlai district, 10 °C to 28 °C in Lunglei, 10 °C to 29 °C in Mamit, -1 °C to 30 °C in Champhai District. The proliferation of Mosquitos is not that fast in Champhai because of large forest extent inspite of the largest temperature range and highest maximum temperature. In contrast highest growth is observed in districts Lawngtlai, Lunglei and Mamit. From correlation analysis, significant positive correlation between TMC and API, TMC and TPR, API and TPR in Aizawl East, Aizawl West, Lawngtlai, Saiha, and Mamit districts was found. While significant correlation is also found among TMC and API, TMC and TPR, TMC and Deaths, API and TPR, API and Deaths, and TPR and Deaths in Kolasib District. While in Champhai district, there is a significant correlation in between TMC and API, TMC and TPR, TMC and % Pf, API and TPR. Serchhip district also revealed a significant correlation in between TMC and API, TMC and TPR, Deaths and TPR. And in Lunglei district a significant correlation in between TMC and API, TMC and Deaths, API and Deaths was found. From the Box plot, we can conclude that during the years 2010-2020 Aizawl East has the largest range of pf %, and Mamit district has the longest range for Annual Positivity Rate and Lunglei district (i.e; has the longest range for Total Malaria Cases among 9 districts. While the range of total deaths was observed in Aizawl west and Mamit and shortest is in Champai.

In this study, comparison test (Bonferroni) or post-hoc test was also used to examine which pair of the districts are significantly different in terms of API, % pf cases and Total malaria cases. On comparing Mean API of Aizawl East with other districts, statistically significantly high difference was found for Lawngtlai, Lunglei, and Mamit and same is the case for Aizawl West ($p < 0.01$). Mean API of district Champhai and Kolasib, was found to be statistically significantly different from Lawngtlai, Lunglei, and Mamit ($p < 0.01$). Statistically significant difference was also found for Lawngtlai vs Saiha, Lawngtlai vs Serchhip, and for Mamit vs Saiha, and Mamit vs Serchhip at ($p < 0.01$). But for Lunglei and Serchhip, statistical high significant difference exists at 1% level of significant. On comparing % pf cases with other districts, statistically significantly high difference was found for Aizawl East with Lawngtlai, Lunglei, and Mamit and same for Aizawl

West ($p < 0.01$). There is also statistically significant difference between Champhai and Mamit at 1% level of significant. Comparison of Malaria cases revealed statistically significant difference between pairs of Aizawl East vs Lawngtlai, Lunglei, and Mamit and same is found for Aizawl West, and Champhai districts at ($p < 0.01$). Statistically high significant difference also exists between Kolasib with Lawngtlai, Lunglei, and Mamit at 1% level of significance. Lawngtlai district is statistically different from Mamit, Saiha, Serchhip with high significance ($p=1$). Further, there is statistically highly significant difference lies between Lunglei and Saiha, Lunglei and Serchhip, and between Mamit and Saiha, Mamit and Serchhip in terms of Malaria cases ($p=1$) Majority of Mizoram population is dependent on farming. Deforestation and ignorance of health awareness are the major causes of malaria spread in Mizoram. One of the most abundant mosquitos those who spread malaria in Mizoram is Anopheles PF and three district (mostly southern part) are having distinct malaria cases. Findings of this study illustrate that in Mizoram, the prevalence of Malaria is more in males than females at the age of 15+, meaning that male needs to be more careful about their daily routine and practices. In Mizoram, malaria awareness is required including spraying DDT around the houses, rooms, walls, and bed and use of deltamethrin treated mosquito's net to reduce the cases of Malaria.

Conclusion

This study is analysis the temporal dynamics of Malaria in Mizoram from 2010 to 2020. Findings showed high incidence of malaria cases in especially in districts of Lawngtlai, Lunglei and Mamit. The forest areas in the districts of Mizoram are the primary contributors to the incidence of malaria in the region. Therefore, it highlights the need for a more intensive approach to combat malaria in forested areas. The forests are home to many malaria vectors, such as mosquitoes, that breed in water pools, leaf litter, and other suitable habitats. Additionally, the forested areas are often difficult to access making malaria control efforts challenging. So, the current measures taken to combat malaria in forested area of Mizoram may not be sufficient to control the disease effectively. Therefore, it proposes the implementation of more stringent measures to prevent and control malaria transmission in these areas. State Vector Borne Diseases Control Programme (Malaria) Mizoram should seriously take various measures such as intensified surveillance and monitoring of malaria cases, targeted vector control interventions, improved access to malaria diagnosis and treatments and community-based education and awareness programs. These measure can reduce

the incidence of Malaria by controlling mosquito populations and promoting prevention measures like the use of insecticide-treated bed nets and proper sanitations. Implementing these measures would require increased resources and efforts, especially in the remote and hard-to-reach forested areas. However, it is essential to intensify control measures to reduce the burden of malaria in these areas and achieve the goal of malaria elimination in Mizoram and India.

References

1. World Health Organization. World malaria report 2017. Geneva: WHO; 2022. Licence:CC BY-NC-SA 3.0 IGO.
2. World Health Organization. World malaria report 2017. Geneva: WHO; 2017
<http://www.who.int/malaria/publications/world-malaria-report-2017/en/> [Google Scholar]
3. World Health Organization. Global technical strategy for malaria 2016–2030; 2015
Geneva: World Health Organization.
4. Dhiman, S., Veer, V., & Dev, V. (2018). Declining transmission of malaria in India: accelerating towards elimination. Rijeka: InTech. Chapter 11
<http://dx.doi.org/10.5772/intechopen.77046>
5. Karuppusamy, B., Sarma, D. K., Lalmalsawma, P., Pautu, L., Karmodiya, K., & Nina, P. B. (2021). Effect of climate change and deforestation on vector borne diseases in the North-Eastern Indian state of Mizoram bordering Myanmar. *The Journal of Climate Change and Health*, 2, 100015.
<https://www.sciencedirect.com/science/article/pii/S2667278221000134>
6. Sarma, D. K., Mohapatra, P. K., Bhattacharyya, D. R., Chellappan, S., Karuppusamy, B., Barman, K., ... & Balabaskaran Nina, P. (2019). Malaria in north-east india: importance and implications in the era of elimination. *Microorganisms*, 7(12), 673.
7. Ministry of Health & Family Welfare (MoHFW), Govt.of India National Vector Borne Disease Control Programme (NVDCP) (2021). Malaria Situation in India.<http://nvbdcp.gov.in>
8. Dev, V., Bhattacharyya, P. C., & Talukdar, R. (2003). Transmission of malaria and its control in the northeastern region of India. *Journal-Association of Physicians of India*, 51, 1073-1082.
9. Mohapatra, P. K., Prakash, A., Bhattacharyya, D. R., Goswami, B. K., Ahmed, A., Sarmah, B., & Mahanta, J. (2008). Detection & molecular confirmation of a focus of *Plasmodium malariae* in Arunachal Pradesh, India. *Indian journal of medical research*, 128(1), 52-56.
10. Prakash, A., Mohapatra, P. K., Bhattacharyya, D. R., Goswami, B. K., & Mahanta, J. (2003). *Plasmodium ovale*: First case report from Assam, India. *Current Science*, 84(9), 1187-1188.

11. Ministry of Health & Family Welfare (MoHFW), Govt.of India.(2018)National Vector Borne Disease Control Programme. Malaria situation from 2015.<https://nvbdcp.gov.in/WriteReadData/l892s/15048331161580734250.pdf>.Accessed 20 may 2021.
12. Zomuanpuui, R., Hmar, C. L., Lallawmzuala, K., Hlimpuia, L., Balabaskaran Nina, P., & Senthil Kumar, N. (2020). Epidemiology of malaria and chloroquine resistance in Mizoram, northeastern India, a malaria-endemic region bordering Myanmar. *Malaria journal*, 19(1), 1-11.
13. Directorate of Health Services, Health & Family Welfare Department, Mizoram (2021). Important Achievements of Health & Family Welfare Department Government of Mizoram (2019-2020). e-book-achievement-2021-2022.pdf (mizoram.gov.in)
14. Lalmalsawma, Pachuau, K. Balasubramani, Meenu Mariya James, Lalfakzuala Pautu, Kumar Arun Prasad, Devojit Kumar Sarma, and Praveen Balabaskaran Nina. "Malaria hotspots and climate change trends in the hyper-endemic malaria settings of Mizoram along the India–Bangladesh borders." *Scientific reports* 13, no. 1 (2023): 4538.
15. Dhiman, S., Rabha, B., Goswami, D., Das, N. G., Baruah, I., Bhola, R. K., & Veer, V. (2014). Insecticide resistance and human blood meal preference of *Anopheles annularis* in Asom-Meghalaya border area, northeast India. *Journal of Vector Borne Diseases*, 51(2), 133.

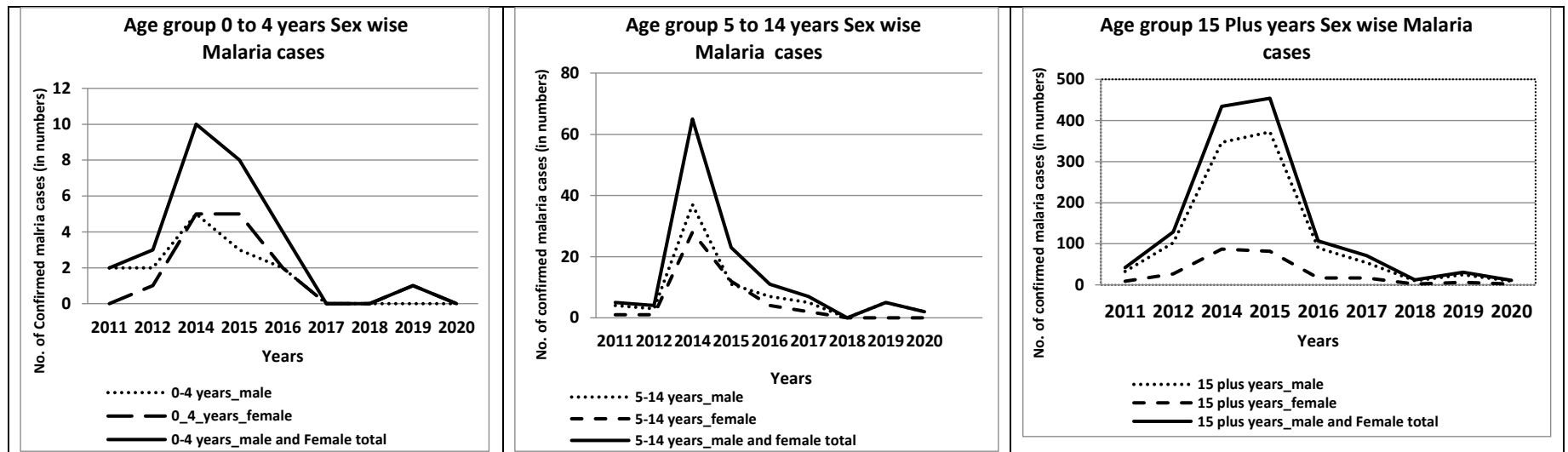


Figure 1: Age-Sex wise confirmed Malaria Cases for Aizawl East District of Mizoram, 2010 to 2020. `

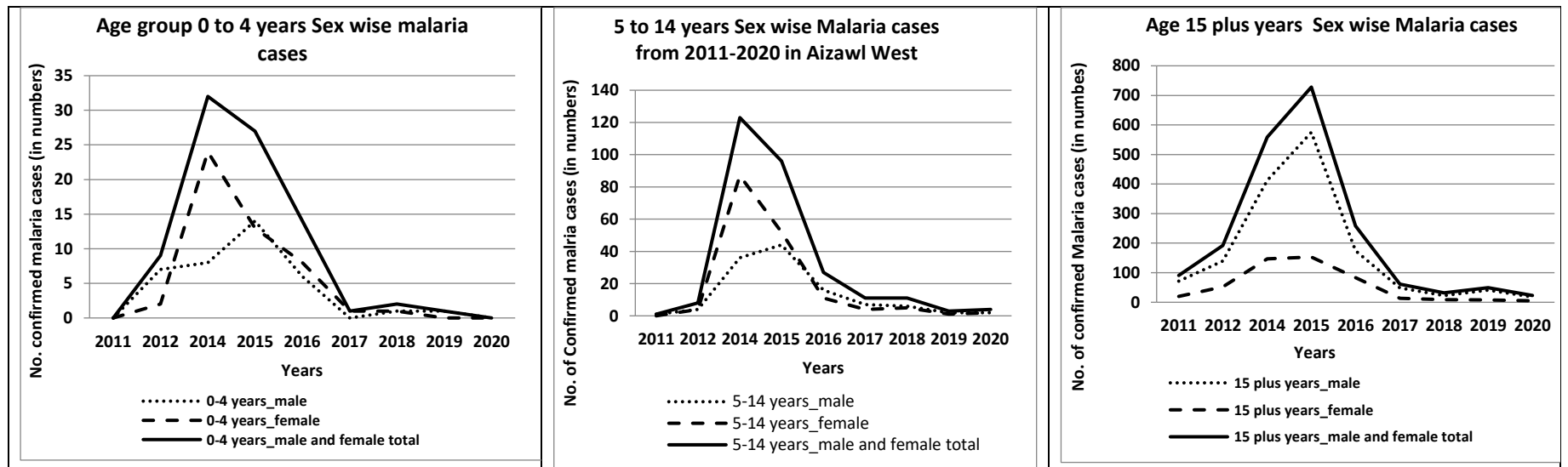


Figure 2: Age-Sex wise confirmed Malaria Cases for Aizawl West District of Mizoram, 2010 to 2020.

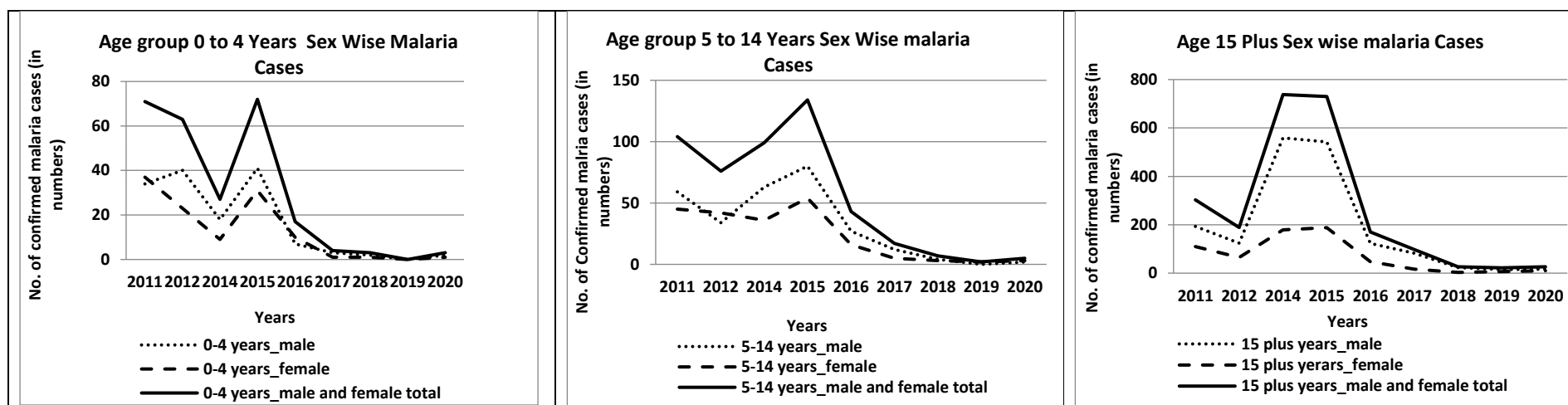


Figure 3: Age-Sex wise confirmed Malaria Cases for Kolasib District of Mizoram, 2010 to 2020.

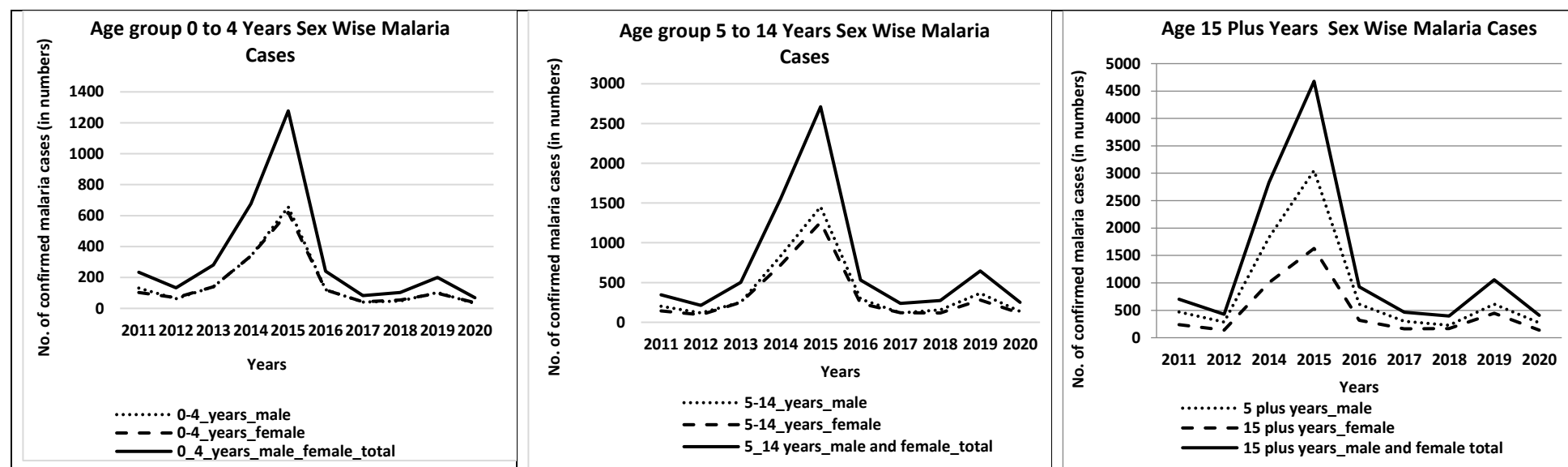


Figure 4: Age-Sex wise confirmed Malaria Cases for Mamit District of Mizoram, 2011 to 2020.

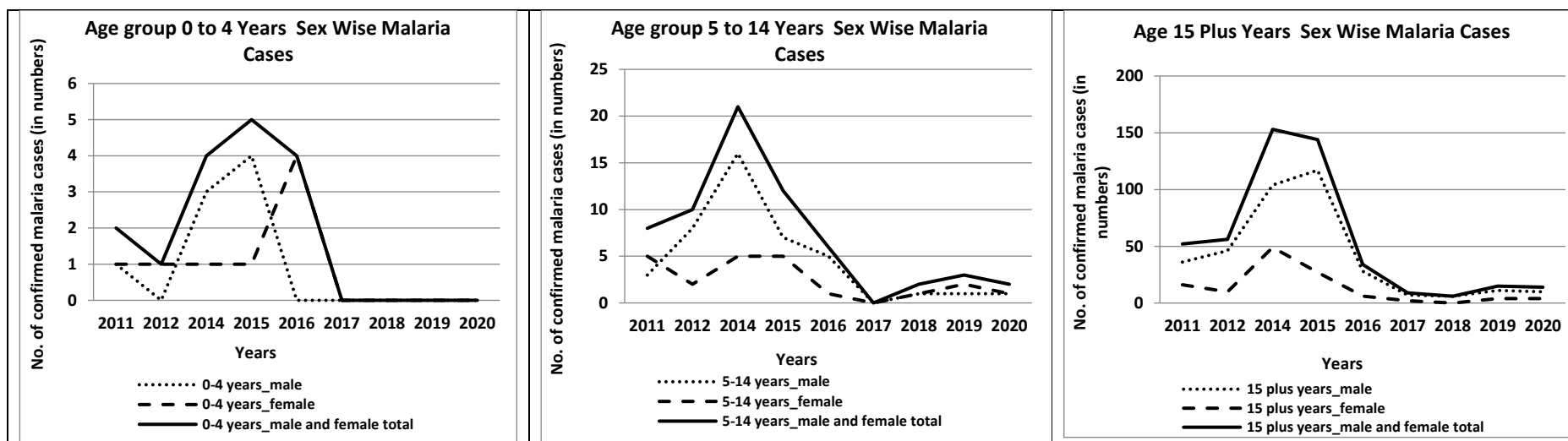


Figure 5: Age-Sex wise confirmed Malaria Cases for Serchhip District of Mizoram, 2011 to 2020.

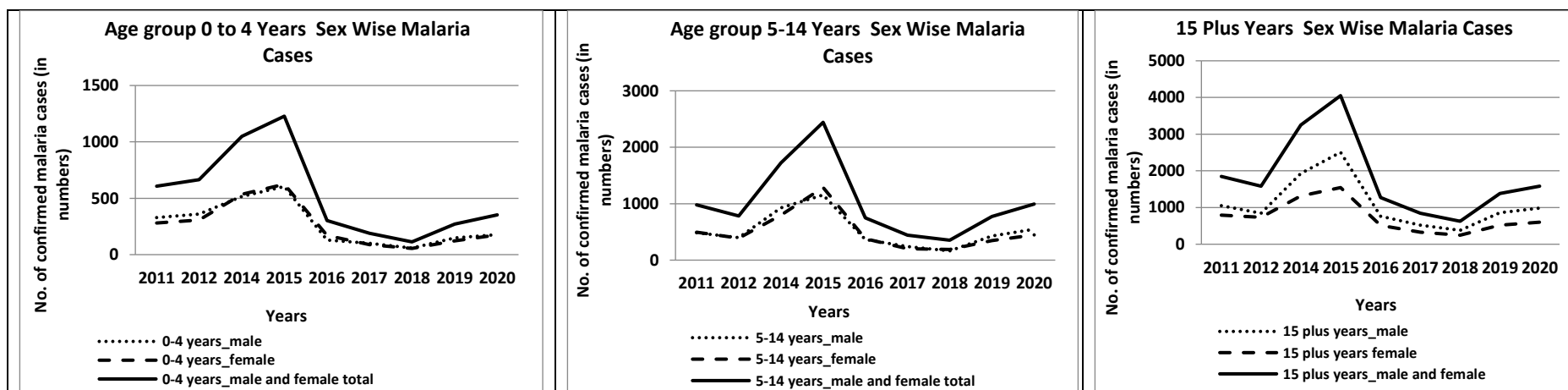


Figure 6: Age-Sex wise confirmed Malaria Cases for Lunglei District of Mizoram, 2011 to 2020.

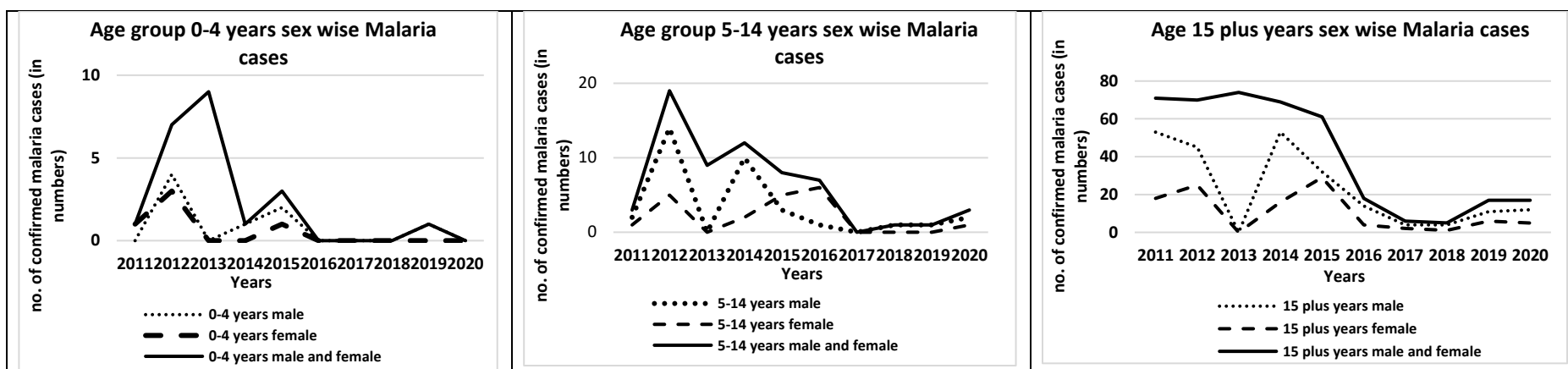


Figure 7: Age-Sex wise confirmed Malaria Cases for Champhai District of Mizoram, 2011 to 2020.

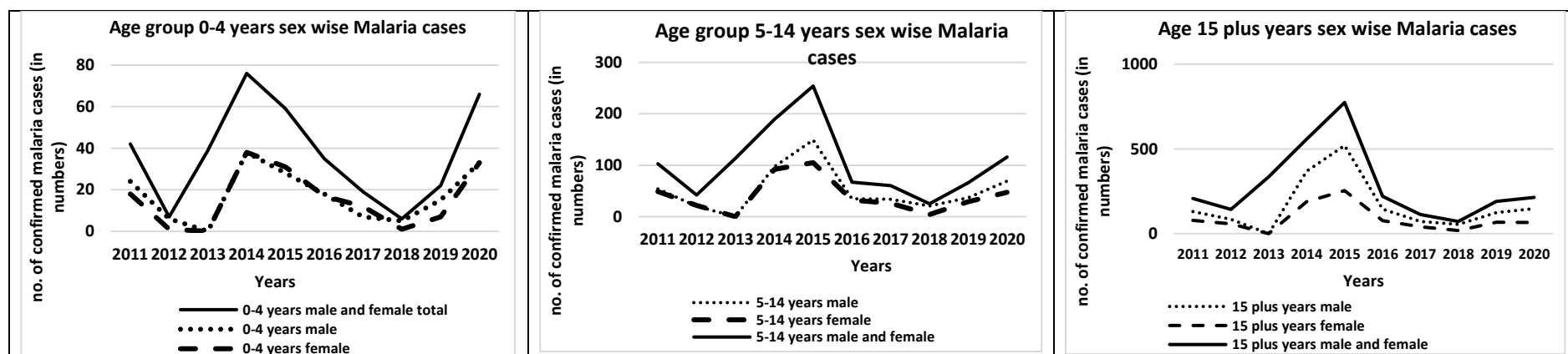


Figure 8: Age-Sex wise confirmed Malaria Cases for Saiha District of Mizoram, 2011 to 2020.

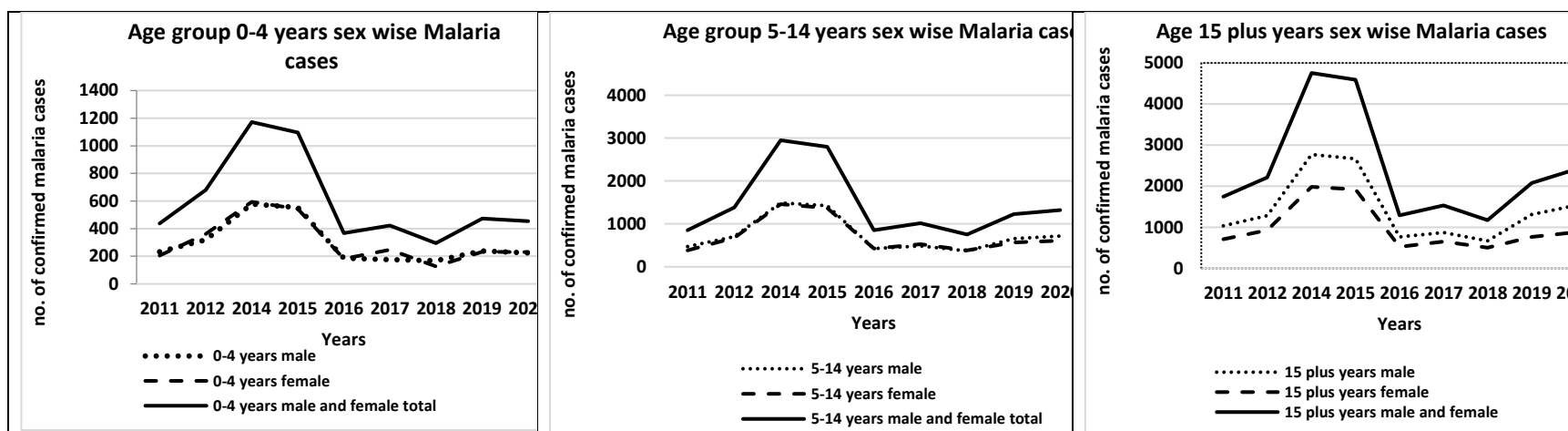


Figure 9: Age-Sex wise confirmed Malaria cases for Lawngtlai District of Mizoram, 2011 to 2020

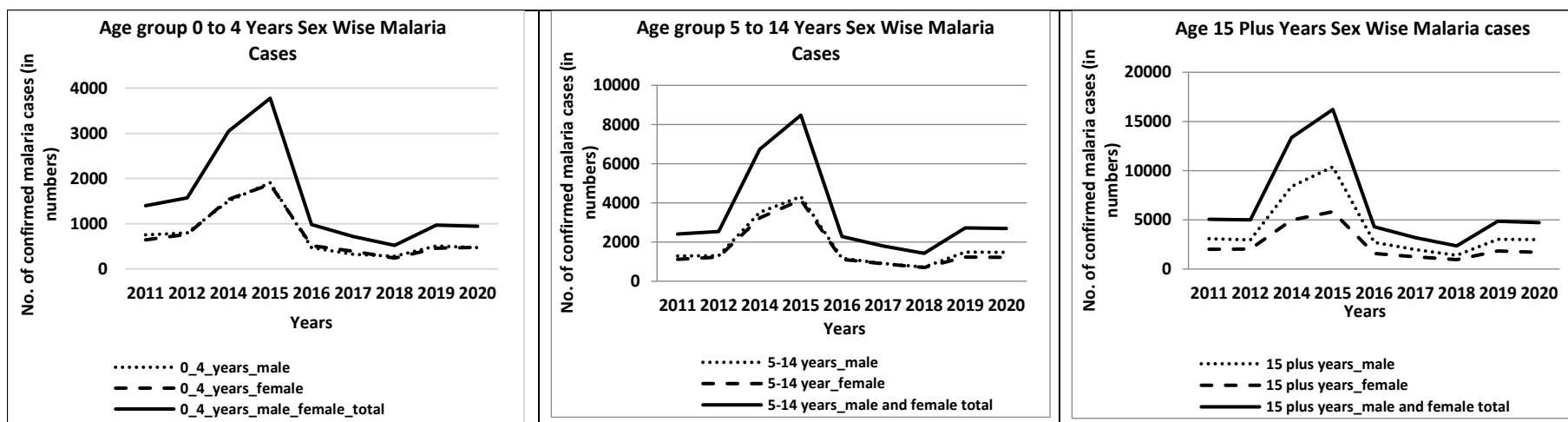


Figure 10: Age-Sex wise confirmed Malaria Cases for Mizoram, 2011 to 2020.

Table 1: Descriptive Statistics for the Indicators Total Malaria cases, Percent Pf, API, Malaria Deaths for Nine Districts of Mizoram, 2010-2020

Districts	Indicator Name											
	Total Malaria Cases			Percent Pf			API			Malaria Deaths		
	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range
Aizawl East	174.5	178.1	497	68.6	21.7	70.3	0.73	0.74	2.02	1.27	1.62	5
Aizawl West	259.4	278.9	825	69.8	19.2	52.1	1.6	1.7	4.9	2.3	3	9
Champhai	53.8	38.2	93	72.1	9.9	33.4	0.37	0.28	0.74	0.64	0.67	2
Kolasib	431.2	446	1357	81.5	15	44	5.3	5.57	17.35	1.45	1.37	4
Lawngtlai	4498.7	2233	6628	90.3	5.3	17.3	33.6	16.7	52.1	3.3	3.1	10
Lunglei	3690.6	2097.5	6653	90.5	3.4	12.1	24.2	13.9	42.8	2.9	3.4	11
Mamit	2365.5	2468	8039	92.5	7	22.1	30.7	31.4	102.3	2.91	3.2	9
Saiha	459.8	317.4	984	75.6	11.4	45.4	7.7	5.5	16.4	0.8	1.2	3
Serchhip	81.9	83.6	256	74.8	15.2	55.4	1.3	1.4	4.2	1.6	1.2	3

Table 2: Correlation of the different indicators of Malaria by different Districts of Mizoram, 2010-2020.

Districts of Mizoram	Indicators	Total Malaria cases	%Pf	API	Malaria Deaths
Aizawl East	API	0.985*			
	TPR	0.787*		0.802*	
Aizawl West	API	0.999*			
	TPR	0.969*		0.974*	
Kolasib	API	0.998*			
	Deaths	0.687*		0.696*	
	TPR	0.918*		0.910*	0.604*
Lawngtlai	API	0.989*			
	TPR	0.861*		0.881*	
Saiha	API	0.997			
	TPR	0.84		0.804	
Champhai	% Pf	0.745*			
	API	0.929*	0.624*		
	TPR	0.984*	0.741*	0.936*	
Mamit	API	0.99*			
	TPR	0.981*		0.970*	
Serchhip	API	0.999*			
	TPR	0.844*		0.843*	0.609*
Lunglei	API	0.996			
	Deaths	0.724*		0.757*	

Note: * indicates that these correlation values are statistically significant @ 5 percent level significance and insignificant results are not shown.

Figure 11: Boxplot for the indicators %Pf, API, and Total Malaria cases, deaths for each of the nine districts of Mizoram,2010-2020

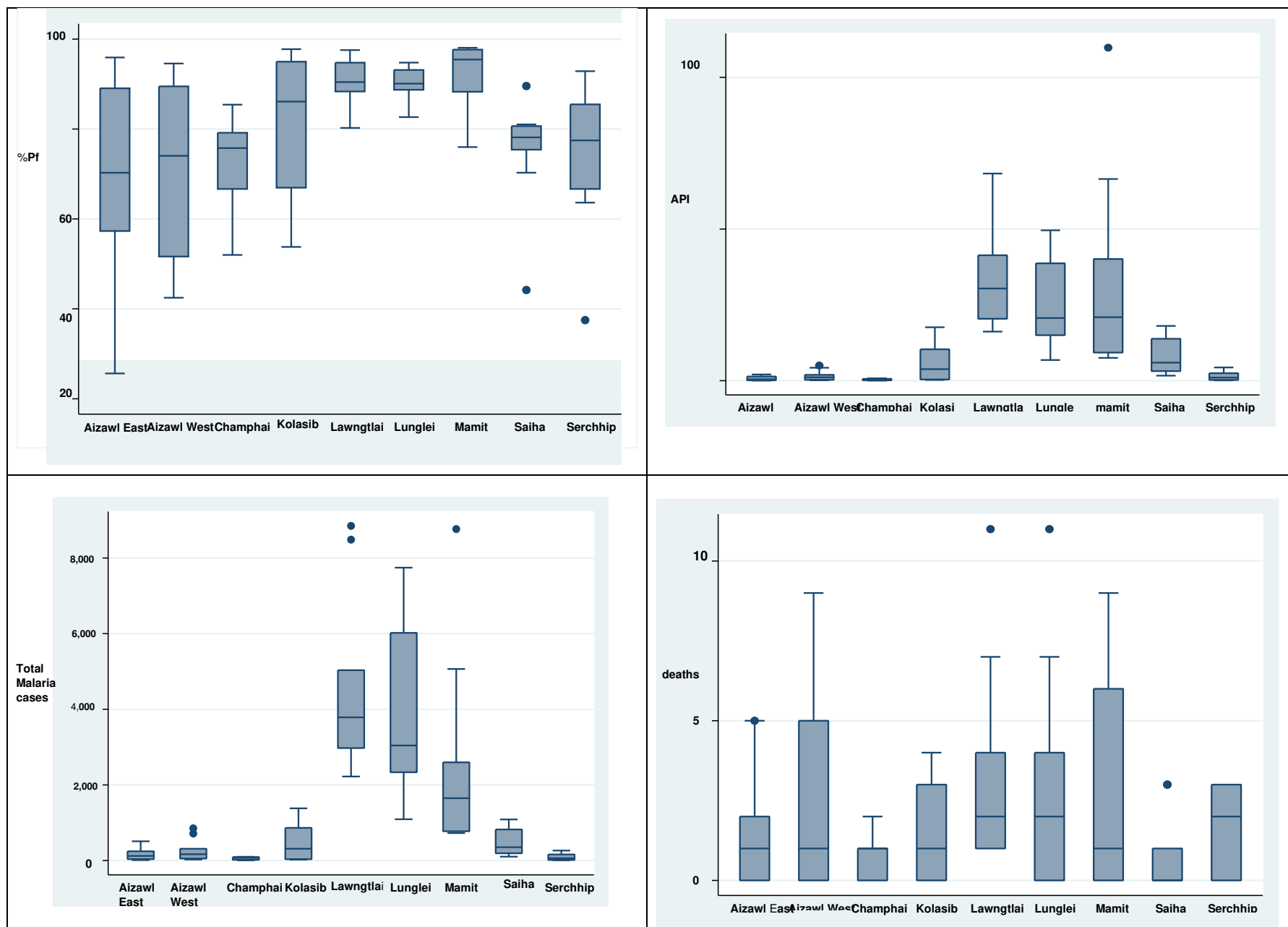


Table 3: Analysis of Variance (ANOVA) table for comparison of indicator API, % Pf , Total Malaria Cases by Nine District of Mizoram, 2010-2020.

Source of Variation	SS	Df	MS	F	P-value	F crit
API						
<i>Between Districts</i>	16649.64	8	2081.21	12.29	0.00	2.043
<i>Within Districts</i>	15241.71	90	169.35			
<i>Total</i>	31891.35	98				
Total Malaria Cases						
<i>Between Districts</i>	263104274.2	8	32888034.28	18.62	0.00	2.043
<i>Within Districts</i>	158948010.5	90	1766089.006			
<i>Total</i>	422052284.7	98				
% Pf Cases						
<i>Between Districts</i>	7844.54	8	980.57	5.48	0.00	2.043
<i>Within Districts</i>	16099.01	90	178.88			
<i>Total</i>	23943.55	98				

Post hoc testing for Comparison of mean of indicators API, Total Malaria Cases, % Pf by District (Bonferroni) of Mizoram,2010-2020.

Row mean-Column mean	Aizawl East	Aizawl West	Champhai	Kolasib	Lawngtlai	Lunglei	Mamit	Saiha
API								
<i>Lawngtlai</i>	32.8705**	32.044**	33.2294**	28.3034**				
<i>Lunglei</i>	23.441**	22.6146**	23.7999**	18.8739*				
<i>Mamit</i>	29.9938**	29.1673**	30.3526**	25.4267**				
<i>Saiha</i>					(-1) 25.8829**		(-1) 23.0062**	
<i>Serchhip</i>					(-1) 32.2983**	(-1) 22.8688**	(-1) 29.4215**	-
Total Malaria cases								
	<i>Aizawl East</i>	<i>Aizawl West</i>	<i>Champhai</i>	<i>Kolasib</i>	<i>Lawngtlai</i>	<i>Lunglei</i>	<i>Mamit</i>	<i>Saiha</i>
<i>Lawngtlai</i>	4324.27**	4239.36**	4444.91**	4067.55**				
<i>Lunglei</i>	3516.18**	3431.27**	3636.82**	3259.45**				
<i>Mamit</i>	2191.09**	2106.18*	2311.73**	1934.36*	(-1) 2133.18*			
<i>Saiha</i>					(-1) 4038.91**	(-1) 3230.82**	(-1) 1905.73*	
<i>Serchhip</i>					(-1) 4416.82**	(-1) 3608.73**	(-1) 2283.64**	
% Pf								
	<i>Aizawl East</i>	<i>Aizawl West</i>	<i>Champhai</i>	<i>Kolasib</i>	<i>Lawngtlai</i>	<i>Lunglei</i>	<i>Mamit</i>	<i>Saiha</i>
<i>Lawngtlai</i>	21.6191**	20.4611*						
<i>Lunglei</i>	21.8584**	20.7004*						
<i>Mamit</i>	23.8105**	22.6525**	20.3505*					

Note: *p<0.05; **p<0.01