Spatial Distribution of Malaria and its Vectors in Selected Districts of Khyber Pakhtunkhwa, Pakistan

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Abstract

Pakistan is considered as a moderate malaria-endemic country but still, 177 million individuals are at risk of malaria that make up roughly 60% of Pakistan's population. The current study has been conducted in the recently merged districts of Khyber Pakhtunkhwa (KP) province of Pakistan, including, districts of Khyber, Orakzai, subdivision Peshawar, subdivision Kohat and subdivision Lakki Marwat. This research work was carried out from October 2017-December 2020 to find out the spatial distribution of malaria, to identify possible hotspots for the disease and its vector mosquitoes in the selected regions based on available data. Spatial distribution was determined using ArcMap 10.8 by making maps. The Malaria prevalence data was analyzed which revealed that Plasmodium vivax cases were more common than Plasmodium falciparum. A total of 5089970 samples were observed during these years, 62148 came out positive, 53930 cases turned out to be P. vivax, 6474 P. falciparum and 1684 were mixed cases. Although cases of malaria were reported throughout the year, infection rates were found to be highest during the months of July-October. From the data obtained, only the data for selected districts were retrieved. Out of total, 52% were males and 48% were females. The current study indicates that malaria prevalence is regulated by intricate collaborations among the hosts and vectors and has a direct relationship with the prevailing conditions of environment and climate. The findings of this study also imply that if the Anopheles vector is not controlled efficiently it might result in repeated incidence in areas which are not endemic.

Keywords. Malaria, Merged Districts of KP, Spatial distribution, Anopheles, Vectors.

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Introduction

Diseases carried by vectors have been confirmed as the chief cause of death and illness in many countries that are not yet fully developed. Humans are infected by five Plasmodium species: Plasmodium vivax, Plasmodium falciparum, Plasmodium oval, Plasmodium Knowles and Plasmodium malaria [1]. The effects of the diseases are not uniform around the world. African region is the most affected, followed by Southeast Asian region. Africa remained to be the most affected region where about 93 % of total cases were observed in the year 2018, the second highest rates were observed in South-East Asia Region, which showed 3.4 % of the total cases, and the East Mediterranean parts of the globe showed 2.1% prevalence [2]. According to WHO World Malaria Report 2019, about eighty five percent of total malaria cases occurred in nineteen nations of India and sub-Saharan Africa (WHO, 2022). Out of total cases globally, six countries bore 50% of the burden. Nigeria is the most affected with 25% cases, followed by Congo with 12% cases, Uganda shares 5% of the burden and Mozambique, Niger and Côte d'Ivoire collectively shared 4% of the burden (WHO, 2022). The decline in mortality was highest (54%) in the WHO regions of South-Eastern Asian, region, a forty percent decline in Africa and 10% in the East Mediterranean. However, the pace of improvements has decelerated during the past five years, showing the likely shifts in malaria case incidence [3]. There are 91 countries and regions that are presently under the threat of malaria transmission. In the previous one and a half century, almost fifty percent of the malaria affected regions in the world got rid of this disease. Out of the 91 countries where malaria is prevalent, 67 are in the monitoring stage of malaria and thirty-two are looking for a strategy to eliminate it [4]. Most of the cases of malaria in Pakistan, Afghanistan, Iran and Iraq are a result of infection with P.vivax, (WHO, 2022). When P. vivax and P. falciparum are present simultaneously in a community, it enhances the probability of mixed infections in an individual [5].

The situation is similar in Pakistan because mixed plasmodium infections are being frequently documented from numerous parts of the country, making the issue even more profound [6]. According to health officials, malaria cases have been observed as being more common in villages and country sides in comparison to cities. Malaria is primarily more common in the Khyber Pakhtunkhwa including the recently merged districts previously called Federally Administered Tribal Areas (FATA), Balochistan, and Sindh [7]. Developing nations like Pakistan are considerably influenced by Malaria, regardless of the control strategies and tactics planned and implemented by the responsible authorities [8]. Pakistan is faced with numerous challenges and problems in the hindrance and control of malaria, such as improper diagnosis, shortage of investigative amenities and delay in possible treatment. Evidence and statistics regarding the load and

dispersal of species of malaria are critical for managing efforts for active control strategies on national and provincial levels. Although Pakistan is one of the regions where diseases carried by vectors are more frequent (Pant, 1987; Schoneberg and Stark, 2012), mosquito biodiversity in the country is under-explored (Khan MA, 1971). Precise identification of vectors is of key importance to plan approaches for supervision of diseases carried by vectors (Capelli et al., 2009). According to the researchers conducted on the vectors population in Pakistan, there are twenty four varying species of anopheles described from across the country which include species such as Anopheles culicifacies and An. stephensi, these are those species of vectors which are known for immunity against organochloride carbamates (Aslam Khan, 1971). According to health officials, malaria cases have been observed as being more common in villages and countrysides in comparison to cities. Malaria is primarily more common in the Khyber Pakhtunkhwa, Balochistan, and Sindh and the FATA (Kakar et al., 2010). So, the current study was conducted to analyze the patterns of malaria, to determine the areas that are hotspots for the disease, to determine the mosquito fauna of selected regions and to prompt priority-based control actions from the concerned authorities.

Materials and Methods

The Study area

This study was conducted in five selected districts of merged districts (ex FATA), Pakistan. The selected areas included districts of Khyber, Orakzai, subdivision Peshawar, subdivision Kohat and subdivision Lakki Marwat. According to the 2017 census, the total population of District Khyber is 986,973, the population of Orakzai District is 254,356, the population of Subdivision Peshawar is 64,691 in, the population of Subdivision Kohat is 118,578 in, and the population of Subdivision Lakki Marwat is 26,359 (Pakistan Bureau of Statistics, 2017) (shown in figure 1sss).

Data collection and Analysis

We obtained data on malaria prevalence from Malaria Control Program (MCP), FATA Secretariat, and Peshawar, Pakistan which is responsible for providing detailed information on prevalent diseases to the health system of the KPK province. Only the data for selected regions was extracted for analysis. Data was analyzed using Microsoft Excel. Diagrams and tables were used for comparison, contrast, and analysis. On a monthly basis, all malaria cases were conveyed from health services in each district in a summarized form to FATA Secretariat. Aggregation of malaria datasets was done at a district level that contained information on the numbers of malaria patients, parasites species i-e P.falciparum, P.vivax and mixed infections, and time period at which the infection peaked i-e months and year, these were then sent to FATA Secretariat, Peshawar, Pakistan for initiating evidence-based control strategies and efficacy enhancement. The spatial patterns of the disease were created in ArcMap10.8 for every selected district individually. An approximate record of populace for individual selected district was obtained from the Pakistan Bureau of Statistics. Malaria annual incidence was calculated using the population data. The yearly and monthly aggregate of malaria incidence for selected districts were evaluated and connived to see the yearly variations of malaria spread between early 2015 and late 2018.

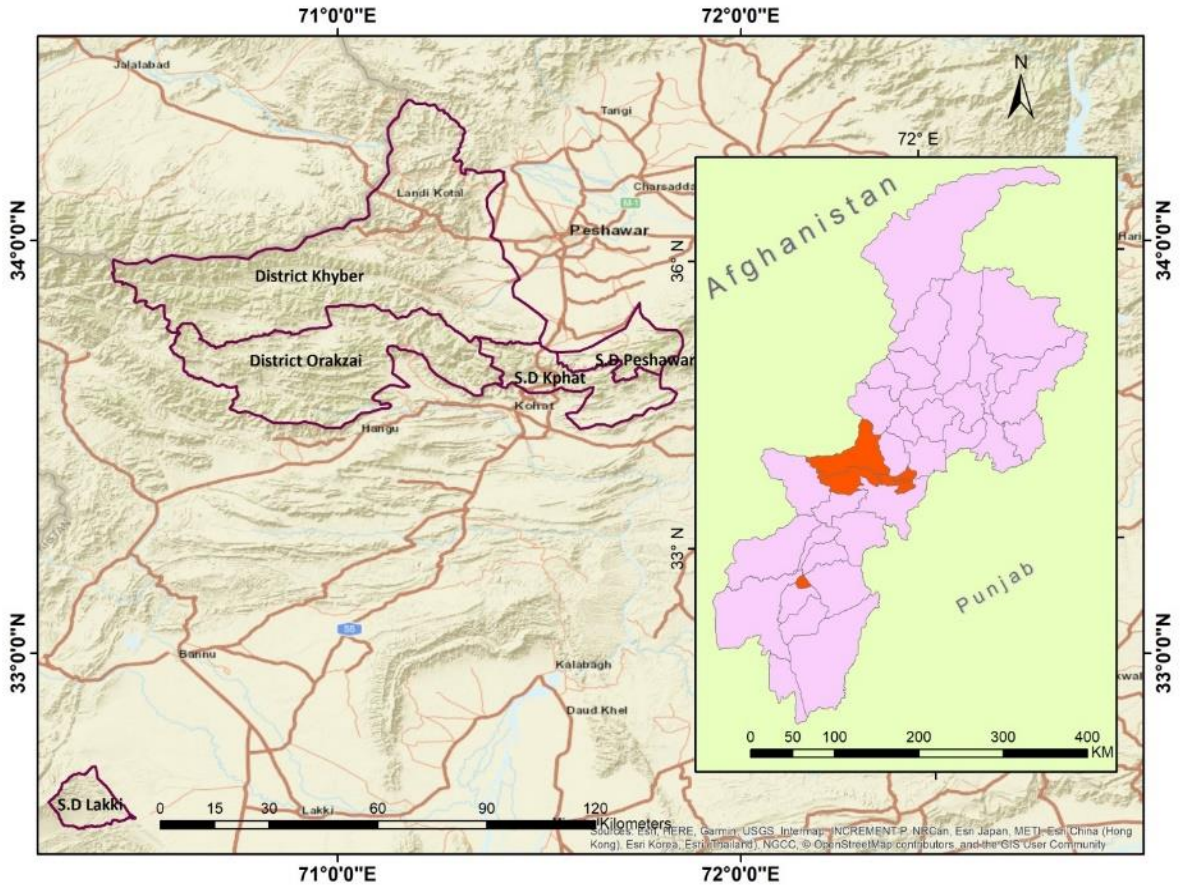


Figure 1. Map of the study areas, KPK, Pakistan, created using ArcMap software, version 10.8, USA, Environmental Systems Research Institute.

Mosquito collection and identification

To measure malarial transmission, a good amount of information about its vectors is essential. To accomplish this goal, entomological studies with Anopheles collection are crucial [9]. An entomological survey was done in each selected district for the collection of Anopheles mosquitoes during the months of July-November in 2018. Samples were collected from various sites in accordance with the standard sampling techniques. The Pyrethroid spray catch method was employed for collection of mosquitoes from indoor sites. Mosquitoes were also collected from outdoor sites such as vegetation and cattle sheds. The collected samples were well-kept-up in tubes and the time and location of site from where they were collected were written on them. Greater proportion of collected mosquitoes was from inside the rooms and washrooms, while specimen from outdoor sites made up for only a small part of the total, approving the endophilic nature of anopheles mosquitoes in Pakistan. These collection tubes were brought to the laboratory for identification of Anopheles mosquitoes in samples collected. Samples were stored using silica gel and later identification was carried out up to species level. Identification of mosquitoes was done

by employing keys given in the Fauna of British India by Ali and Rasheed [10].

Results

Malaria incidence in selected districts from year 2015-2018

Table 1: Malaria incidence in the selected areas from 2015-2018

District	Year	Total Screened	Total Positive cases	Percentage/Slide Positivity Rat
Subdivision Peshawar	2015-2018	36254	3385	9.33%
Subdivision Kohat	2015-2018	58150	8552	14.71%
Subdivion Lakki Marwat	2015-2018	57825	6616	11.4%
Orakzai	2015-2018	90291	3868	4.28%
Khyber	2015-2018	266477	39727	14.90%

Table 2: Percentage of Malaria incidence in the selected areas

Year	Total Screened	Total Positive	Percentage
2015	119776	16084	13.42%
2016	115993	18626	16.05%
2017	185713	15466	8.32%
2018	87514	11972	13.6%

A total of 508997 slides were observed during the years 2015-2018 in the health facilities of the selected districts, out of which 62148 were found positive for malaria (Table 1). Malaria cases were documented in all areas that were selected during this term. The highest malaria incidences were mainly distributed in the districts of District Khyber, Subdivision Kohat and Lakki Marwat. A total of 508997 slides were observed during the years 2015-2018 in the health facilities of the selected districts, out of which 62148 were found positive for malaria. The maximum occurrence rate 16% was observed in 2016, and the minimum incidence of 8.32% occurred in 2017 (Table 2, Figure 1). An unstable but noticeably dropping trend of annual malaria incidence was recognized. Malaria cases were documented every month, and the peak period occurred between May and November, during which approximately more than half of the yearly malaria cases were reported. The months with the lowest malaria incidence were

January, February, and December during the 2015-2018 period, whereas the highest malaria incidence was reported during the months of August to November.

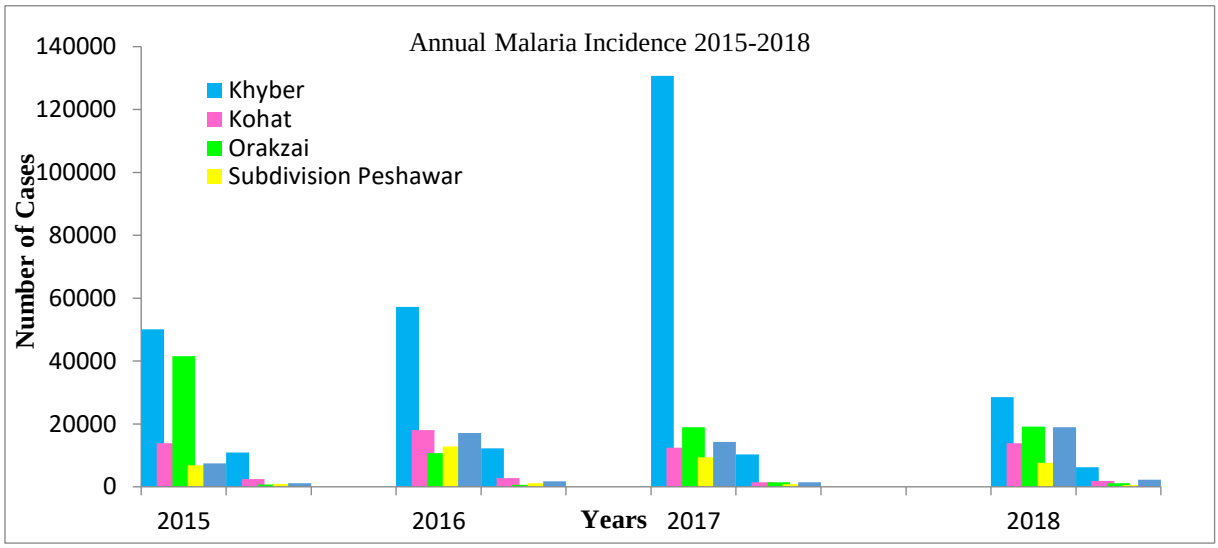


Figure 1. Annual Malaria Incidence, 2015-2018

Reported cases of malaria in Health Facilities of District Khyber in 2015-2018

The results of the analysis of malaria data for the year 2015 demonstrate that the majority of malaria cases were reported from nine health facilities of District Khyber (Figure 2). 3235 cases were reported from Civil Hospital Jamrud which shows a prevalence rate of 29.5% from total cases. 2409 cases were reported from BHU Ali Masjid, showing a prevalence rate of 21.9%. 870 (7.9%) from AHQ Hospital Landi Kotal, 5.3 % (590) from Dogra Hospital, 3.9 % (435) from BHU Kam Shalman, 3.5 % (390) from CD Qadam. The results of the analysis of malaria data for the year 2016 shown in figure 2 reflect that the greatest number of malaria cases were reported from Civil Hospital Jamrud which shows a prevalence rate of 34.4% (4221) from total cases. 1927 cases were reported from AHQ Hospital Landi Kotal showing a prevalence rate of 15.7 % and 10% (1236) from BHU Ali Masjid (Figure 2). The results of the analysis of malaria data for the year 2017 shows that the highest number of malaria cases were reported from Civil Hospital Jamrud which shows a prevalence rate of 16.7 % (1728) out of total cases. 1462 cases were reported from THQ Dogra Hospital showing a prevalence rate of 14.2%. 12.2% (1259) from BHU Ali Masjid. The results of the analysis of malaria data for the year 2018 shows greatest number of malaria cases were reported from AHQ Hospital Landi Kotal. which shows a prevalence rate of 34.4% (1014) from total cases. 940 cases were reported from CHC Janbaz Kalay showing a prevalence rate of 15.7 % and 10% (518) from CH Jamrud (Figure 2).

Malaria incidence in District Orakzai in 2015 – 2018

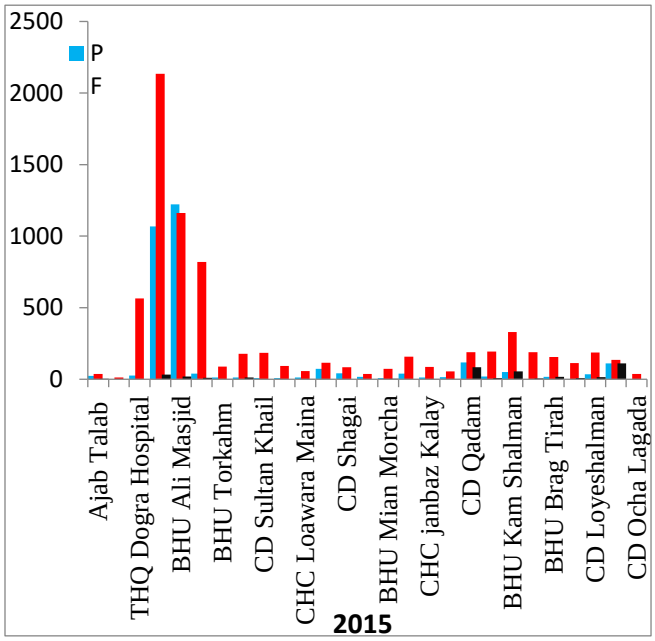
Health facility wise analysis showed the highest number of cases from CHC Karghan 9.1% (63), followed by Tatni Essa Khel with 55 (8%) cases, CD Janda 50 (7.2%), CD Zera 46(6.7%) and CHC Trakho Sam 43 (6.2 %). CD Mela Orakzai had the lowest number of cases 0.2 % (2) (Figure 3). During the year 2016 the highest number of malaria cases was reported from CHC Paloosai 40, with a prevalence rate of 6.16% from total cases (Figure 3). A total of 38 cases were reported from CH Kalaya showing a prevalence rate of 5.85 %. 4.7% (31) from Mishti Mela. Year 2017 shown in figure 3 demonstrates that the greatest number of malaria cases were reported from CH Tarkho Sam 181, with a prevalence rate of 12.8% from total cases. 165 from CHC Chapri Ferozkhel showing prevalence rate of 11.6%. In CHC Karghan the prevalence rate was 12.24% (173) and 9.0 % (128) from CH Ghiljo (Figure 3). Lowest numbers were reported from CD Shankhel 0.06% (1), 0.13% (2) from CHC Dowli, and 0.2% (4) cases from BHU Dranr. In the year 2018 the greatest number of malaria cases were reported from Ramazan Medical Center 419, which shows a prevalence rate of 37.3% (1121) (Figure 3). 151 cases were reported from Yasin Medicos showing a prevalence rate of 15.7 %. 10% (518) cases were reported from CH Aukab Medical Center. The lowest numbers were reported from Al Syed Medical Center 0.25 (3) and 0.6% (10) cases from Ahmad Health care center. Figure 7 shows potential hot spots in District Orakzai from where malaria cases were reported.

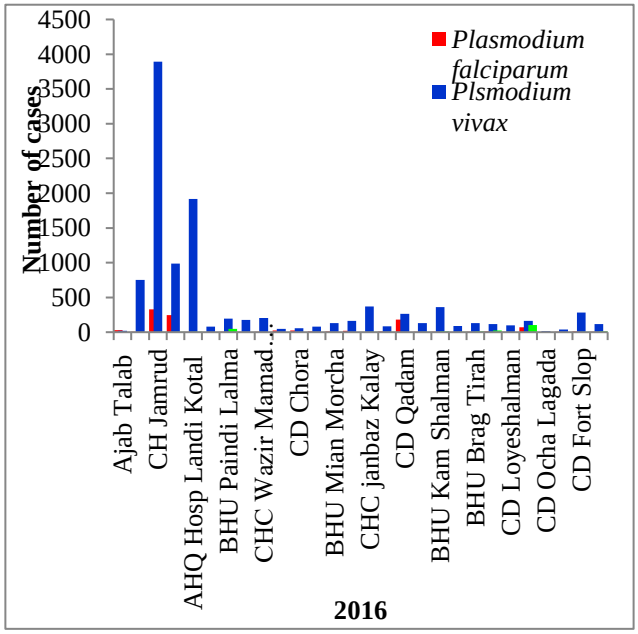
Malaria incidence in District Lakki Marwat from 2015 – 2018

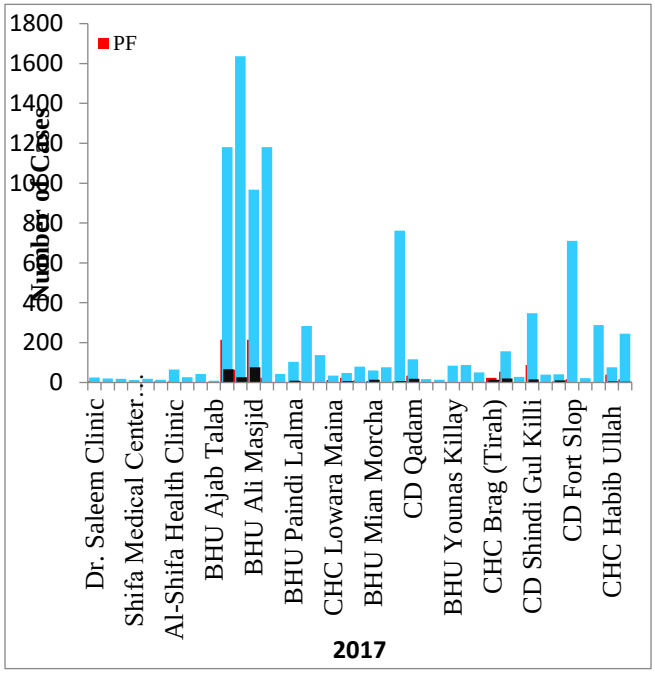
Analysis of malaria data for the year 2015 in District Lakki Marwat shown in figure 4 reveals that the greatest number of malaria cases was reported from CHC Madi Khel, 174 showing a prevalence rate of 15.7% from total cases. 129 cases were reported from CH Tikka Khan showing a prevalence rate of 11.6 %. 12.5% (138) from BHU Gabar Bagh and 10.3% (114) from CD Ghundi Hassan Khel. The lowest numbers were reported from Nimat Clinic Pvt 0.09% (1), Sabir Clinic Pvt 0.36% (4), Nasibullah Clinic Pvt 0.36% (4), Muhammad Bashir Clinic Pvt 0.4% (5). Figure 7 shows potential hot spots of malaria in Subdivision Lakki Marwat.

In 2016, a total of 17161 cases were screened out of which 1740 came out positive. Plasmodium vivax cases accounted for 94.9% (1649), Plasmodium falciparum cases 1.8 % (33) and 3.3% (58) were mixed infections. Peak months were September with 212 cases (12.1%), 207(11.8 %) cases of malaria occurred in the month of August, followed by July 206 (11.8%) and 202(11.6%) cases were reported in June. The lowest numbers were recorded in February 163 (9.36%). In 2017, a total of 14316 cases were screened for malaria in district Lakki Marwat, out of which 1474 came out positive. Plasmodium vivax cases accounted for 93.6% (1380), Plasmodium falciparum cases 3.6 % (54) and 2.7% (40) were mixed infections. Peak months were July with 217cases (14.7%), August with 205 (13.9%) cases, 182 (12.3%) cases of were recorded in the month of October, 180 (12.2%) cases in September, 162(10.9%) cases occurred in November and 152 (10.3%) in March. The lowest numbers were recorded in January 122 (8.2%). Data for April, May and June weren't available from the record. The results of the analysis of malaria data for the year 2018 shown in figure 4 reveal that a total of

18912 cases were screened out of which 2298 came out positive. The highest number of malaria cases was reported from CHC Madi Khel 282, which shows a prevalence rate of 34.4% (1014) from total cases. 279 cases from BHU Dabak Sardar Khel, showing prevalence rate of 15.7 %. Of the total cases, 10% (250) were reported from CHC Tikka Khan, 9.8% (227) from BHU Kotka Arbab Khan. Lowest number of cases was reported from CD Sargara Muhammad Khan 3.2% (74) and 3.8% (88) from CD Abdullah Khan. Figure 7 shows potential hot spots in Subdivision Lakki Marwat from where malaria cases were reported.







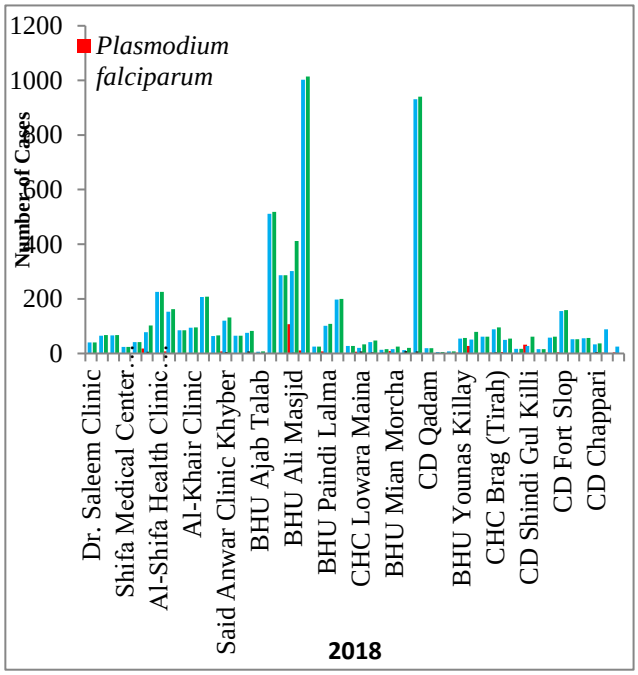


Figure 2. Reported cases of malaria in Health Facilities of District Khyber in 2015-2018

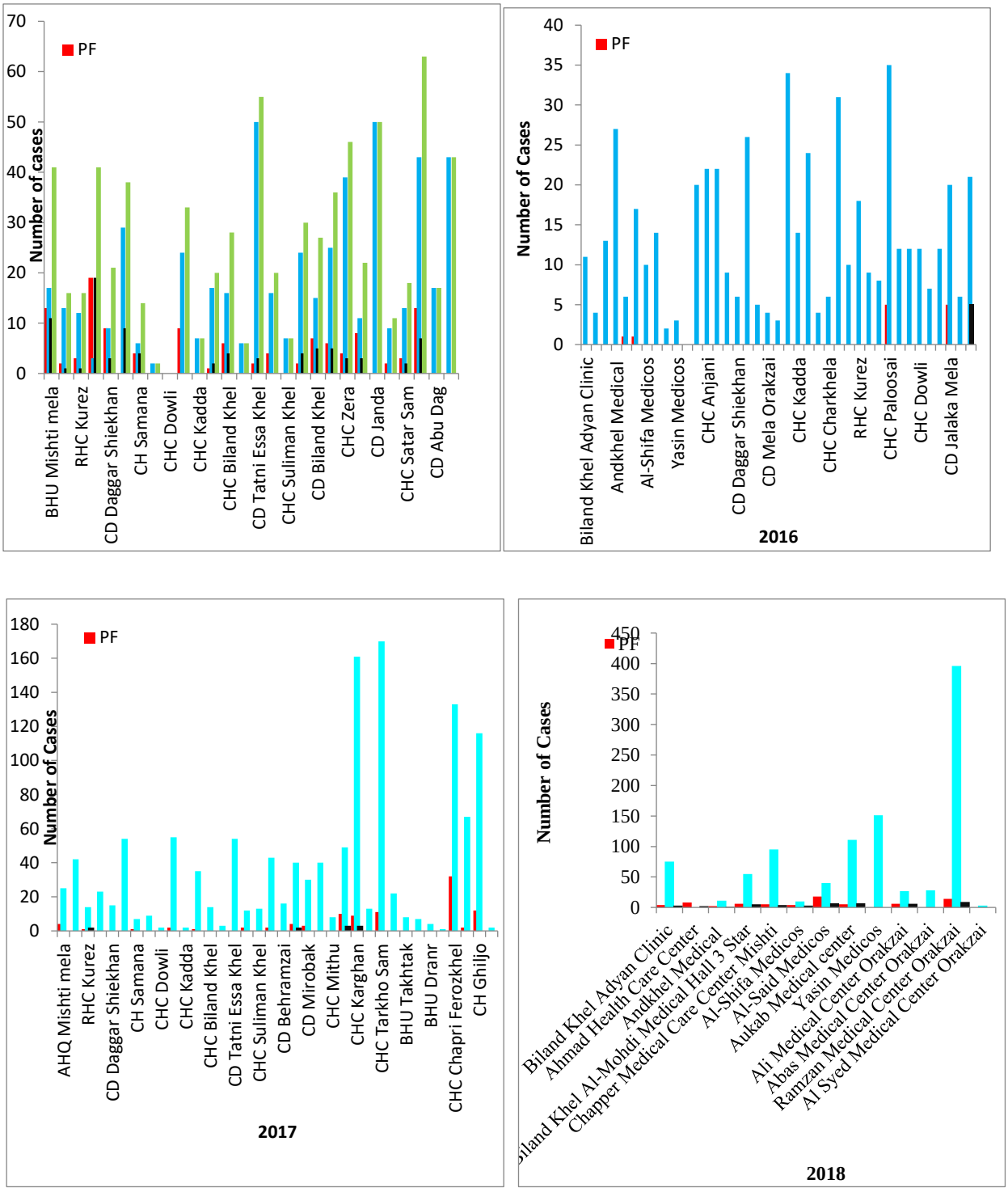


Figure 4. Reported cases of malaria in Health Facilities of District Lakki Marwat in 2015-2018

Malaria incidence in District Kohat in 2015 – 2018

Malaria incidence in District Peshawar in 2015 – 2018

Analysis of the data for the year 2015 in Subdivision Peshawar shows the highest number of cases from CH Shamshatoo 184(20.3%), BHU Boora 160 (17.7%), 20(2.21%) Mosa Dara, 124 (13.7%) CHC Said Azam (please see figure 6). Lowest numbers were reported from BHU Faridi 11(1.2%), 24(2.6%) CD Ilyas Kaly, 24 (2.6%) from CD Ayub Kaly, 43(4.7%) CD Amir Nawaz, 46 (5.09%) CD Tila Kaly and 48(5.3%) BHU Gul Akbar Analysis of the data for the year 2016 in Subdivision Peshawar shows the highest number of cases from CD Mosa Dara 245 (21.03%), CH Shamshatoo 205(17.5%), BHU Boora 151(12.9%), CHC Said Azam 134 (11.5%). Lowest numbers were reported from CD Faridi 9(0.7%), CHC Ayub Kalay 39(3.3%), CD Amir Nawaz 28(2.4%) and RHC Kohi 58(4.9%). Data analysis for the year 2017 in Subdivision Peshawar shows the highest number of cases from CH Shamshatoo 259 (31.3%), CHC Said Azam 77(9.3%), BHU Boora 74(8.9%) , BHU Janah Kor 65(7.8%) . The lowest numbers were reported from CHC Ayub Kalay 14(1.6%), BHU Faridi 15(1.8%), CD Ilyas Kalay 21(2.5%) and BHU Yar Ali 32(3.8%). Analysis of the data for the year 2016 in Subdivision Peshawar shows the highest number of cases from CH Shamshatoo 149(30.2%), BHU Janah Kor 57(11.5%), CD T ila Kalay 40(8.1%). Lowest numbers were reported from BHU Faridi 12(2.4%), CHC Ayub Kalay 7(1.4%), BHU Hassan Khel 16(3.2%), BHU Yar Ali 16(3.2%) and BHU Pastwani 17(3.4%).

Malaria incidence in District Kohat from 2015 – 2018

Analysis of the data for the year 2015 in Subdivision Kohat shows the highest number of cases from BHU Paya 22.4% (547), followed by Bhu Akhurwal 15.4% (378), CHC Ghariba 10.8% (264) and BHU Turki Ismail Khel 7% (172). Lowest numbers were reported from Busti Khel 1.3% (34), BHU Suney Khel 1.9% (48), CD Malak Qayum 2.2% (560 and BHU Sherakai 2.3% (57). Analysis of the data for the year 2016 in Subdivision Kohat shows the highest number of cases from BHU Paya 16.7% (471), followed by Bhu Akhurwal 14.6% (412), BHU Turki Ismail Khel 13.2% (372) and CHC Ghariba 11.1% (314). The lowest numbers were reported from CD Khaista Hussain 0.10% (3).

The analysis of the data for the year 2017 in Subdivision Kohat shows the highest number of cases from BHU Bhu Akhurwal 16.6% (243), CD Sheen Dand 8.9% (131), CD Dalil Khel 8.8% (129), BHU Paya 8% (117) and BHU Arrakhel 6.8% (100) (please see figure 5). The lowest numbers were reported from MCH Zarghon Khel 0.6% (9), CD Khaista Hussain 1.09 %(16), BHU Busti Khel 1.3% (19),CD Malak Qayum 1.15% (17) and CD Attarwial 1.8% (27), BHU Arrakhel 0.8% (24), BHU Suny Khel 1.2% (34) and CD Attaraiwal 1.7% (50). Analysis of the data for the year 2018 in Subdivision Kohat shows the highest number of cases from BHU Akhurwal 22.3% (411), BHU Paya 10% (185), CD Naseem 9.9% (183), CH Zarghon Khel 9.1% (169) and CD Malik Ashiq 6.9% (128). The lowest numbers were reported from Busti Khel 1.4% (27), MCH Zarghon Khel and CD Khasita Hussian 1.6% (31).

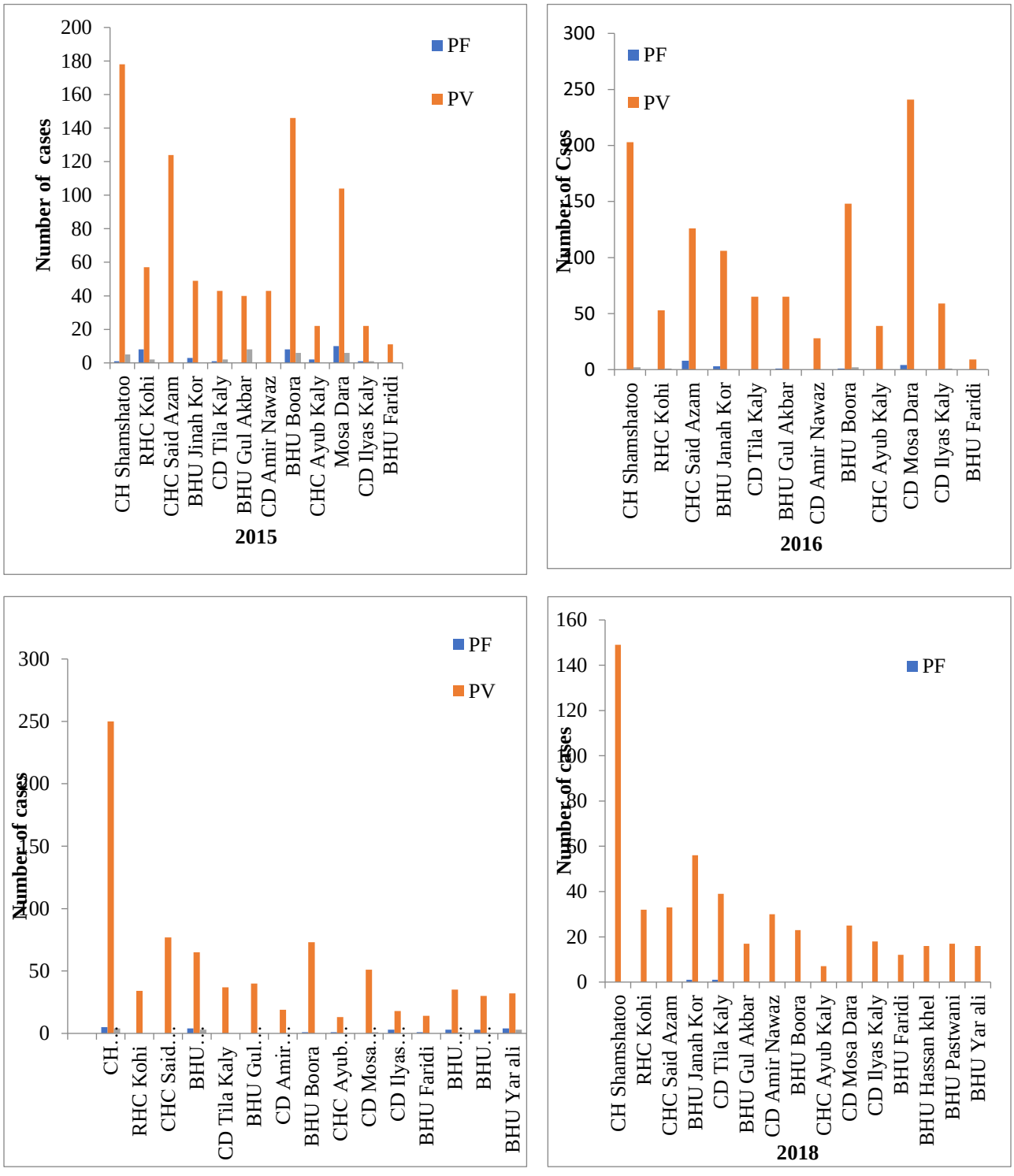


Figure 3. Reported cases of malaria in Health Facilities of District Peshawar in 2015-2018

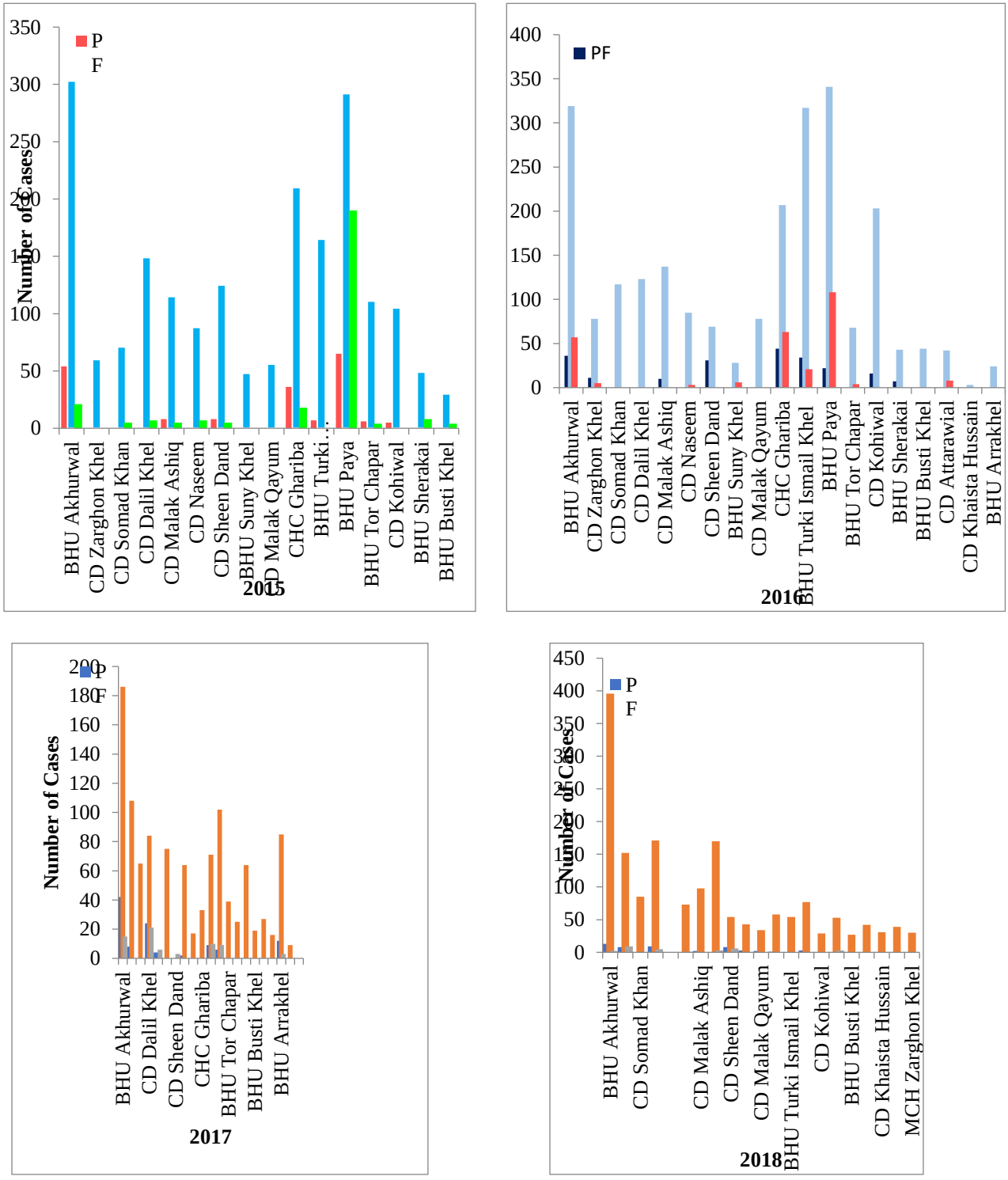


Figure 4: Reported cases of malaria in Health Facilities of District kohat in 2015-2018

Spatial Distribution maps of Malaria in Selected Districts

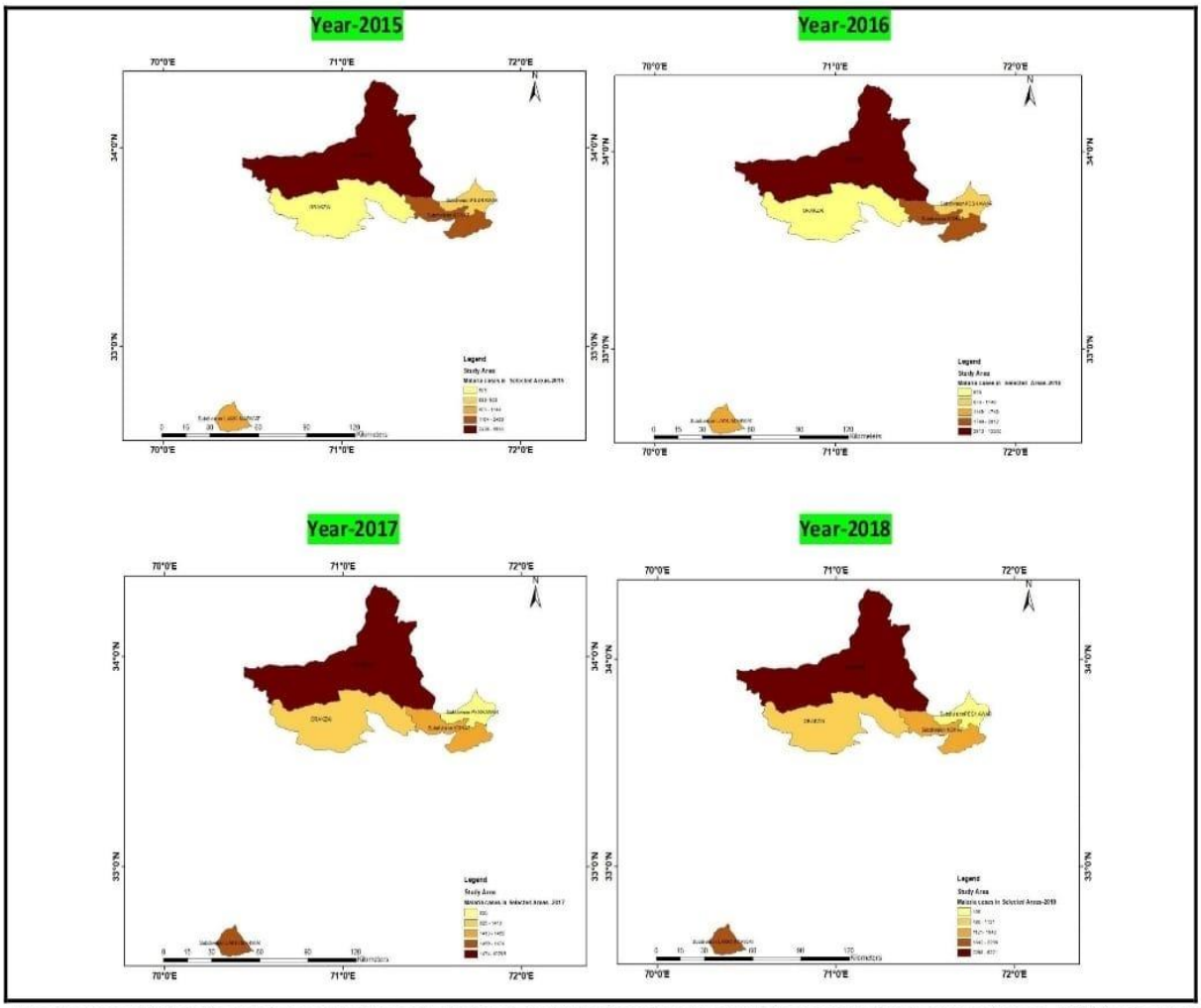


Figure 8: Spatial Distribution maps of Malaria in Selected Districts

Discussion

Malaria is increasingly becoming a severe health issue in Pakistan. Malaria cases differ noticeably in diverse locations and cannot be evaluated precisely due to non-availability of information. Consequently, it has been tough to estimate the accurate rates of malaria in Pakistan. The analysis of data and consequent results in this study showed that there is a constant increase in malaria cases from 2015 to 2018. In Pakistan around 3.5 million supposed and confirmed malaria cases are documented annually. The history of the disease shows the inefficiency of health sector in Pakistan to fight and control this disease, as it is still the primary hazard to public health in Pakistan. The endemicity of malaria is variable in different provinces and even in different cities where the climates vary. Province wise breakdown indicates that

during 2017 maximum cases were reported from Khyber Pakhtunkhwa 30%, Sindh 26.5%, Federally Administered Tribal Areas (FATA) 21.9%, Baluchistan 20.5% and Punjab with the least epidemiology of 1.1% [11]. The National Malaria Control Program has documented a 6 times surge in P. falciparum infection during the last ten years. The rise of P. falciparum infection throughout the country can be interlinked with chloroquine drug resistance. Also, the weather in autumn is warmer that raises the chances of transmission. Similarly control strategies are inapt and inefficient. The malaria epidemiology is influenced by several different aspects of the environment and socioeconomic conditions that back the vector growth and in turn, boosts the relationship between parasite and host [12]. All the reported cases of malaria from 2015-2018, belonging to the districts selected for the study were included in this research work. The total number of malaria cases were 62088 during the period 2015-2018.The results of data showed that majority 52 percent of the cases were males. Data and information from various parts of Pakistan report that males are affected in higher numbers by malaria than the females which is in accordance with the current findings. These findings coincide with the findings of [13] who found that the number of malaria cases among males were 64% while females showed a prevalence rate of 36% in the Punjab province.

All the stated patients of malaria were separated into three age groups. An assessment was carried out, incidence rates were found to be highest (59.7%) in adults, which consisted of age group of 14 years and above, followed by age group 5-14 years reported (27 %) of all malaria cases, the age group consisting of patients less than five years showed lowest incidence rates (13.3%). Similar outcomes were attained from a study by [14], conducted in Quetta, where the younger patients from age 1-10 showed 15% prevalence whereas the age groups above 10 years showed higher prevalence. Malaria rates changed based on seasonal fluctuations as well. A higher frequency of cases was documented in the months of August, September, October, November and December. In the present data analysis, higher incidence was found in post-monsoon period. [15] concluded that the period after monsoon is a highly favorable time for malaria infection. Shahid and Nawaz, (2012), suggested that there was substantial seasonal disparity of vivax and falciparum malaria. Plasmodium falciparum is more common in autumn and reaches its peak during winter, while Plasmodium vivax arrives in spring and peaks towards the end of summer [16].

The species-wise distribution of malaria in this study showed 86.8% P. vivax, 10.4% P. falciparum and 2.8% mixed infections out of 62088 total cases. A similar study by Khattak et al., (2019) from Punjab reported species wise prevalence of malaria as: 66.7 % vivax malaria, 23.7% falciparum malaria and 9.6% were mixed infections. Entomological survey revealed the presence of mosquitoes from three genera which included Culex, Anopheles and Armigeres, Culex being represented by Cx.quinquefasciatus and Cx.mimeticus, Anopheles being represented by An.stephensi, An.maculatus, An.culicifacies and An.annularis and Armigeres being represented by Ar.subalbatous.

Conclusions

Malaria, one of the most ancient and deadly diseases of humankind, can and should be eradicated by the year 2050. Malaria will not be eradicated under a business-as-usual scenario. Specific and essential actions are required at country, regional and global levels to ensure that eradication is achieved. The endemicity of malaria is variable in different provinces and even in different cities where the climates vary. Pakistan is confronted with huge problems in the supervision and control of malaria, availability of authentic facts and figures on the dispersal and load of malaria is vital for administering countrywide and regional efforts and for analysis and effective treatment of the disease. This study specifies that the dynamics of malaria infection are determined by complicated correlations between host, vector, parasite species, and are directly dependent on the conditions of climate. Our findings also show that Plasmodium vivax and Plasmdium falciparum may trigger major epidemics in the regions we included in this study unless effectively eradicated. A step of vital importance in dealing with vector population is entomological testing, which helps in taking rapid actions. The results of this study also prove that malaria is more prevalent in ex FATA, predominantly in the regions we included in this research work.

Recommendations

The public should be encouraged to adopt effectual methods of managing water to put off breeding of vectors. Better techniques of self-protection should also be introduced. Implementing advanced vector assessment techniques. Well planned, multifaceted studies on vector mosquitoes and the aspects of their growth and disease epidemiology are advised to explore the seasonality, distribution and dynamics of malaria infection and its promoters in local environments. The efforts to control should be concentrated on the regions included in this study, specifically District Khyber, District Kohat and subdivision Lakki Marwat, focusing on the hotspots where prevalence of malaria is maximum.

Author Contributions: SN & SG conceived and designed the study; MG, TB and SB collected data, analysed and wrote the manuscript. SN, SR, AAS reviewed, edited, and offered feedback. SR approved and submitted.

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Declarations

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