A COMPREHENSIVE STUDY ON REDUCED PREVALENCE OF MALARIA FROM 2014 TO 2022 IN BARPETA DISTRICT, ASSAM, INDIA

A research project report submitted to Research Cell, B.H. College (in association with Research, Innovation and Extension wing of IQAC, B.H. College)

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Declaration

We hereby declare that this report is the result of our own research work which has been carried out under the guidance of Dr. Suruchi Singh, Assistant Professor of Zoology Department of B.H. College, Howly.

We further declare that this report as a whole or any part thereof has not been submitted to any university (or institute) for the award of any degree or diploma.

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Abstract

Malaria had been causing havoc among the people since decades, although during the time period 2014-22, malaria cases decreased haphazardly in Barpeta district. Analysing the yearly trend of all the 7 Block PHCs, it was found that initially those blocks which were in category 1 in 2014 (having higher API) were marked under Category 0 by 2022 having API equal to zero. This study was conducted to mark the decreasing variation in malaria cases and to find the significant factors responsible for the declining trend and also factors necessary for complete elimination of malaria. Epidemiological data, rainfall & temperature data and other data regarding malaria were collected as secondary data and used to analyse different attributes. A questionnaire based household survey was done to collect primary data on various factors. Statistical analysis through Pearson's correlation method is used on different data sets of both primary and secondary data. The Long-Lasting Insecticidal Net (LLIN) distribution was most effective among the other control & preventive measures. Education had its impact mostly on the awareness of people on preventive measures. Almost 73% of the surveyed households belong to Muslim community and almost 88% of them belong to general category; Dichlorodiphenyltrichloroethane (DDT) spray was witnessed by the most people in comparison to other control measures. For a complete elimination of malaria, the low Annual Parasite Index (API) should be maintained; male adults should be taken care of in terms of the disease; better financial conditions should prevail.

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ABBREVIATIONS

Abbreviation	Full Form
ABER	Annual Blood Examination Rate
ACT	Artemisinin Combination Therapy
API	Annual Parasite Index
BSC	Blood Smears Collected
DDT	Dichlorodiphenyltrichloroethane
DVBDC	District Vector Borne Disease Consultant
FAAMCH	Fakhruddin Ali Ahmed Medical College and Hospital
IEC	Information, Education and Communication
IQAC	Internal Quality Assurance Cell
IRS	Indoor Residual Spraying
ITBN	Insecticide-treated Bed Net
ITN	Insecticide-treated Bed Net
KAP	Knowledge, Awareness, Practices
LLIN	Long-Lasting Insecticidal Net
NRHM	National Rural Health Mission
Pf	*Plasmodium falciparum*
PHC	Primary Healthcare Centre
Pv	*Plasmodium vivax*
RDT	Rapid Diagnostic Test
WHO	World Health Organization

INTRODUCTION

Malaria is a vector-borne disease, which humans have been fighting for decades. It is caused by a eukaryotic protozoan parasite of the genus *Plasmodium*. Of the four species of *Plasmodium*, *P. falciparum* and *P. vivax* are the most common parasites and may be fatal, while the other two namely; *P. malariae* and *P. ovale* are rare and less fatal of the disease. The female *Anopheles* mosquito is the vector that transmits the parasites to people through bites. The primary and secondary host of the malaria parasite is the female *Anopheles* mosquito and human respectively. Malaria results in symptoms like fever, chills, headache, nausea, vomiting, diarrhea in humans, usually after a few weeks of being bitten.

Earlier, malaria was very common in people and also the fatality rate of malaria positive patients was very high, causing it to be considered epidemic. In the year 2000, 238 million malaria cases were globally reported and in 2019, 229 million malaria cases were estimated in 87 malaria endemic countries. India contributes to about 77% of the total malaria in South East Asia. In India, in the year 2000, 20 million malaria cases were marked which then reduced to 2.5 million by 2019. This percentage drop in malaria cases was about 87.5% and death percentage decrease was about 73.9%. Malaria had been made notifiable in 31 states or Union Territories around that time period. Percentage of decline in the year 2019 as compared to 2018 is as follows: Odisha - 40.35%, Meghalaya - 59.10%, Jharkhand - 34.96%, Madhya Pradesh - 36.50% and Chhattisgarh - 23.20%, Assam - 17.3%. 29,999 malaria cases, along with 13 mortality cases, were reported from across the Assam state in 2012. Assam witnessed a declining trend to 7,826 cases, with 6 deaths, as per report in 2016. It can be seen that in Barpeta District of state Assam, total number of malaria positive cases in 2014 was 98 which then decreased to 3 by 2022 with zero deaths reported.

Reduction in morbidity and mortality from malaria are attributed to the improved vector control measures, such as providing Long-Lasting Insecticidal Nets (LLINs) to residents, by spraying DDTs in filthy and contaminated regions and by the application of malathion fogging in every household. Furthermore, blood collection (active collection, passive collection) for microscopic examination, early diagnosis, and treatment are procured to examine and counter each malaria case throughout the Barpeta District. Socio-economic factors markedly education and income with increasing literacy rate has also been an established reason behind the declining trend of malaria cases. As stated by National Vector Borne Disease Control Programme (NVBDCP) and World Health Organization (WHO) guidelines, rapid diagnostic test (RDT) kits allow in early detection of plasmodial antigens making the surveillance system robust by early diagnosis and fast initiation of treatment. Treatment with Artemisinin-based combination therapies (ACTs) had been deployed while imposing a countrywide withdrawal of monotherapy using oral artemisinin for preserving its efficacy. The awareness of malaria symptoms, its transmission, prevention and treatments protocols is closely related to the implementations of malaria control programs.

The Global Fund partnership is designed to accelerate the worldwide disease fight against AIDS, tuberculosis, and malaria. In India, the Global Fund for malaria is approved to support the Ministry of Health & Family Welfare, National Vector Borne Disease Control Programme (NVBDCP), the Ministry of Health & Family Welfare along with the Government of India. NVBDCP aims to eliminate malaria throughout the country i.e. by achieving zero indigenous cases by 2030 and maintain malaria-free status in regions where malaria transmission has been lowered or completely eliminated. So, this research is done to find the significant factors responsible for the declining trend of malaria cases in Barpeta district and also factors necessary for complete elimination of malaria. The project will point out an important insight to that group of people that are more prone to this deadly disease. Also it will intensify the management bodies of Barpeta district to be more assistive and constructive towards that attribute or factor. Moreover this study will cite an example to the disease management authorities of other districts and states in strengthening their policies and subsequently making the entire nation malaria free.

Objectives

a. Study of the epidemiological data and the declining trend of malaria in relation with age, sex factor, climatic factors (rainfall & temperature), control and preventive measures taken by the concerned authorities.
b. Conduction of questionnaire survey to study socio-economic factors associated with malaria and awareness of the general public.
c. Finding of significant factor(s) responsible for the declining trend of malaria cases and also factors necessary for complete elimination of malaria.

International status

Treatments such as Artemisinin combination therapies (ACT) were found to be quite effective in reduction of infectiousness in the patients compared to previous first line treatments, if the therapy is applied before gametocytaemia (Okell, L.C. et al, 2008). In areas such as Northwest Ethiopia, there has been a significant reduction in the number of malaria cases over 17 years but the drop was mainly contributed by reduced infection of *Plasmodium falciparum* whereas *vivax* malaria is still prevalent. (Tesfa, H. et al, 2018). The intervention tools currently available can most likely reduce transmission but clearing of malaria is not possible without involving the local community. Therefore, strong political and financial support among the countries with the common goal of reducing malaria is totally necessary (Dhiman, S. 2019). The 2021 SRWG annual meeting gave regional stakeholders, including NMCPs and APMEN partner institutions, the chance to identify research priorities for surveillance and response in the Asia Pacific region and highlight unmet challenges and barriers, as well as to promote building capacity through training and helpful partnerships. (Sirimatayanant, M. et al, 2023). The evidence supporting the relationship between malaria prevalence and climatic factors has always been controversial and the limiting knowledge buffers the progress in the Global Malaria Program to reduce the cases of malaria in a global perspective. In the last two decades, there has been significant reduction in the disease burden in almost all the countries of Asia Pacific, with a clear positive linear association between malaria incidences, annual minimum temperature and annual precipitation (Wang, C. et al, 2023).

National status

- **Other states of India**

  For developing accurate forecasts for malaria, ARIMA models of time series analysis emerged as a simple and dependable approach for assessing the climatic aspects of the disease (Kumar, V. 2014). In rural or tribal areas of India, particularly in sixteen states, including seven northeastern and nine central states, malaria infection is a serious public health concern (Sharma, R. K. et al, 2015). In 2019 and 2020, malaria cases remained predominant in five states of India: Jharkhand, Orissa, Uttar Pradesh, Chhattisgarh and West Bengal (according to NVBDCP). Forest areas remained the area of focus for malaria transmission due to favourable human and environmental factors. A study conducted in rural areas in Uttar Pradesh gave us an idea regarding the social problems of malaria; several participants had the misconception that there are other ways to spread malaria, such as drinking contaminated water, touching, eating contaminated food, and so on. Even knowledge of any government initiative for the eradication and management of mosquito-borne malaria was relatively limited (Kumar, S. et al, 2022). In the first detailed study of declined rate of malaria cases in Purulia district of West Bengal, it was concluded that LLINs distribution among the inhabitants have significantly contributed to the reduced infection (Pradhan, S. 2022).

- **North-eastern states of India**

  Malaria is significantly endemic in many parts of North East India, and *P. falciparum* is responsible for most of the cases. Northeast India's efforts to eradicate malaria are hampered by highly effective primary vectors and newly emerging secondary vectors. Many of the high transmission zones in NE India are the tribal belts, which are difficult to access. In these areas, active molecular monitoring, treatment of asymptomatic carriers, and active surveillance are all urgently needed. (Sarma, D.K. et al, 2019). In India, National Malaria Elimination Programme has targeted malaria elimination by 2030 but the main issue is the constantly increasing resistance of 1º malaria vectors to insecticides in Central India with forested regions, and the high percentage of asymptomatic and submicroscopic malaria indicating hidden parasite reservoirs in these regions (Ranjha, R. 2021). Studies conducted in Meghalaya showed that the reducing trend is mainly contributed due to ITN and household indoor sprays. Widespread asymptomatic infections and seropositivity among children under five point to the persistence of low-level *Plasmodium* transmission in this area (Sarkar, R. et al, 2021).

- **Assam**

  Several studies are conducted regarding the malaria prevalence in many areas of Assam, as well as North Eastern parts of India. Studies in the tea estates of Nagaon and Udalguri districts of Assam give us an idea about the malaria epidemiology and associated risk factors. The prevalence rate decreases with age, suggesting the development of a protective immunity. *P. falciparum* is the primary cause of the stable malaria transmission that is endemic to the tea estates. In the research locations, promising intervention strategies may be able to significantly lower the prevalence of malaria (Rabha, B. et al, 2012). The prevalence of the disease is found to be correlated with lower income, dwelling type, distance to a health sub-center, knowledge and awareness of malaria, daily mosquito bites, and use of bed nets. (Yadav, K. et al, 2014). In India, particularly in States like Assam with predominantly tribal inhabitants, malaria is a serious public health issue. 90% of India's malaria burden is carried by states with higher tribal population. Despite the efforts to control malaria with the help of long-lasting insecticidal nets distribution, rounds of indoor residual spray, introduction of bi-valent rapid diagnostic tests and artemisinin combination therapy, malaria remained consistent in certain parts of Assam which suggests the need of awareness in community (Ahmed, R. A. et al, 2022).

Study Area

The project area is Barpeta district of Assam state situated in India.

(a) Latitude & Longitude: latitude of 26º19'49.52''N and a longitude of 91º0'14.6''E or 26.330421 and 91.004055 respectively.

(b) Boundary: Baksa district in the North, Nalbari district in the East, Kamrup and Goalpara district in the South and Bongaigaon district in the West.

(c) Area: 2,764 km² (2011 census).

(d) Population: As per 2011 census, the population of Barpeta district is found to be 1,693,622. Out of which male population is found to be 867,004 and female population is 826,618.

(e) Literacy Rate: 63.81 % in average. Male literates – 4, 99,038 and female literates – 3, 98,020.

(f) Topography: It varies from low-lying plains to highland with small hillocks in the South-West corner of the Barpeta district, namely Baghbar, Fulora and Chatala overlooking the mighty Brahmaputra River.

   a. Rivers – The River Brahmaputra flows from east to west across the southern part of the district. Its tributaries that flow through the district are Manah, Kaldia, Pohumara, Palla, Bhelengi, Marachaulkhowa, Beki and Nakhanda. Pohumara and Kaldia join near Barpeta town to form Nakhanda whereas Palla and Beki join with Nakhanda to form Chaulkhowa. The water bodies cover an area of 396 km².

   b. Forests – The total forest area is around 22701 hector. And deciduous forest alone covers around 18824 hector.

   c. Wetlands – 32 in numbers

   d. Soil – Soil types found are sandy, sandy loamy and forest-soils.

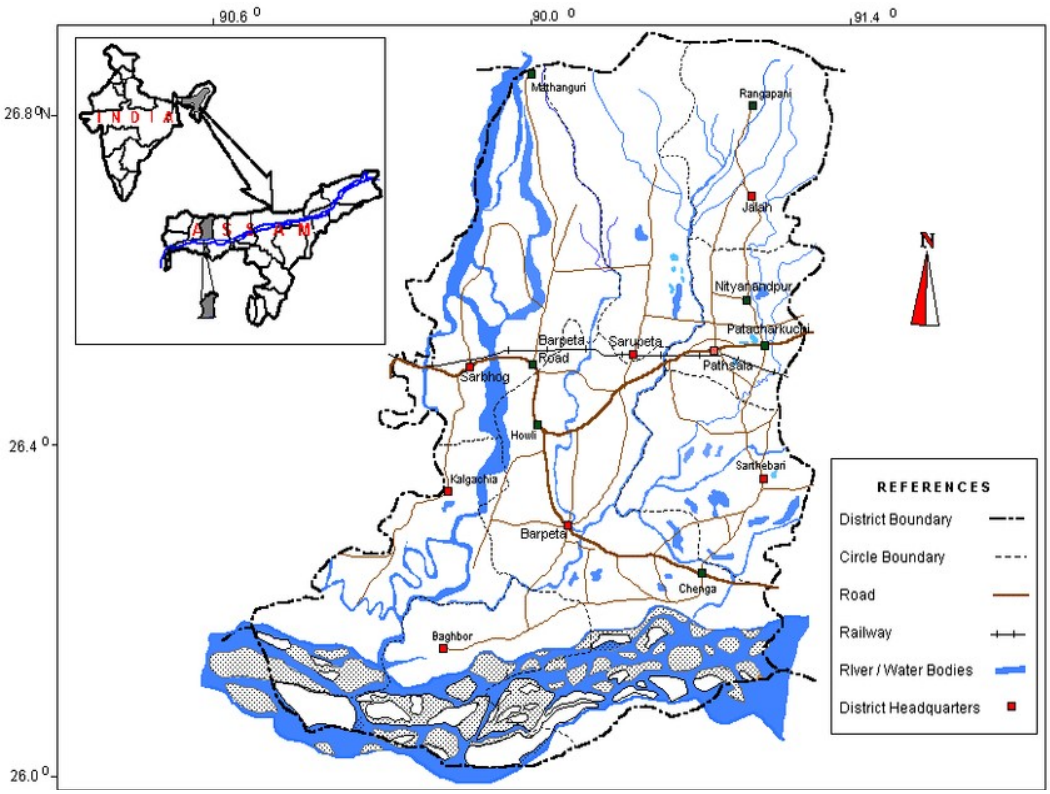

Fig 1: Location map of Barpeta district.

(g) Seasons: Tropical monsoon climate of the district provides two distinct seasons – summer and winter. The summer season of March to May is followed by the monsoon from June to September where the warmest month is April. This is followed by cold winter from October to February where the coldest month is January.

(h) Rainfall: The district typically receives about 82.07 mm (3.32 in) of precipitation and has 49.99 rainy days (13.7% of the year) annually.

(i) Temperature: Average temperature is 27.55ºC (81.59ºF). The highest and lowest temperature recorded is 33.4ºC (92.1ºF) and 9.3ºC (48.74ºF) respectively.

Collection of Secondary Data

Secondary data were collected from the District Malaria Office located at Office of The Joint Director Health Services, Barpeta, Assam at the consent of DMO. Data consisted of PHC-wise epidemiological data (2014-2022), malaria line listing data (2014-2022) (age, sex, detection date etc. of positive cases), data of malaria awareness programs held in the district from 2014 to 2022, data of distribution of ITBN, LLIN, IRS data, fogging data and data of DDT spraying programs from 2014-2022. Secondary data of month-wise average rainfall and month-wise average temperature was also collected for the time period 2014 to 2022 from reliable Google websites.

Collection of Primary Data

Primary data were collected by questionnaire based survey method. An area (village) under each PHC was selected purposively for survey, based on the highest prevalence of malaria in the past 9 years. Each PHC was visited to know about the malaria cases scenario of areas falling under that PHC. Then households were selected randomly in each area for the survey. Information was collected by first forwarding a consent form to the respondent to take their consent in accordance with research ethics. The questionnaire included questions mainly on education, income, religion, caste of the respondent (family head) along with questions about respondent's knowledge on malaria, control measures and awareness received by the respondent and family.

Tab 1: Information of the survey areas.

Sl No.	Survey area	Block PHC
1	Barapetta	Barpeta Road
2	Ananda Pur	Bhawanipur
3	Gadhersali Pam	Chenga
4	Tapeswara	Kalgachia
5	Baghbar	Mandia
6	Khandakar para	Nagaon
7	Singimari	Nityananda

The description of the survey areas (according to 2011 census) are as follows-

(1) Barapetta (under Barpeta Road Block PHC) –
   a. Total no. of households – 210
   b. Total no. of population – 918
   c. Literacy rate – Information not available

(2) Anandapur (under Bhawanipur Block PHC) –
   a. Total no. of households – 656
   b. Total no. of population – 3558; 1865 are male and 1693 are female.
   c. Literacy rate – 47.78%, male literacy rate is 51% and female literacy rate is 44.24%.

(3) Gadhersali Pam (under Chenga Block PHC) –
   a. Total no. of households – 432
   b. Total no. of population – 2112; 1077 are male and 1035 are female.
   c. Literacy rate – 42.47%, male literacy rate is 51.07% and female literacy rate is 33.53%.

(4) Tapeswara (under Kalgachia Block PHC) –
   a. Total no. of households – 835
   b. Total no. of population – 4093; 2123 are male and 1970 are female.
   c. Literacy rate – 40.48%, male literacy rate is 45.08% and female literacy rate is 35.53%.

(5) Baghbar (under Mandia Block PHC) –
   a. Total no. of households – 678
   b. Total no. of population – 3707; 1925 are male and 1782 are female.
   c. Literacy rate – 47.23%, male literacy rate is 54.65% and female literacy rate is 39.23%.

(6) Khandakar Para (under Nagaon Block PHC) –
   a. Total no. of households – 89
   b. Total no. of population – 444; 230 are male and 214 are female.
   c. Literacy rate – 31.08%, male literacy rate is 33.48% and female literacy rate is 28.50%.

(7) Singimari (under Nityananda Block PHC) –
   a. Total no. of households – 119
   b. Total no. of population – 556; 274 are male and 282 are female.
   c. Literacy rate – 76.26%, male literacy rate is 80.29% and female literacy rate is 72.34%.

Data Analysis

The epidemiological data of malaria (2014-2022) was studied for the different information like API, ABER and species of parasite causing malaria. Accordingly, different tables were designed. The malaria cases per year was arranged under *Pv*, *Pf* and mixed infection to check the reduction of malaria cases with respect to species. The API and ABER for each year were plotted against the malaria cases to look for any mentionable pattern in them. Also the API data was used to place blocks under certain categories having specific API criteria.

Tab 2: Block-wise categories according to API criteria.

Block Category	**Criteria**
Category 0: Prevention of re-Establishment Phase	The block with 0 malaria case.
Category 1: Elimination Phase	Blocks having API < 1 per 1000 population.
Category 2 : Pre-Elimination Phase	Blocks having API ≥1, but < 2 per 1000 population.
Category 3 : Intensified Control Phase	Blocks having API ≥ 2 per 1000 population.

Like the epidemiological data, the malaria line listing data (2014-2022) was also reviewed for information like gender and age group of malaria patients and tables were constructed. The missing data for gender and age group was estimated by linear interpolation method.

The data of IEC activity of different years were rearranged year-wise. Again the missing IEC activity data for three years were estimated by linear interpolation method. The data were analyzed to find the effectiveness of each awareness method in reducing the malarial infection over the years.

The information from the survey was converted into tabulated forms for the ease of study. The tables made were based on different factors – education, income, religion & caste and on different topics like knowledge of public regarding malaria, control measures and awareness programs received by the public.

Statistical Analysis

Possible statistical analyses were performed on different data sets of both primary and secondary data in SPSS software (version IBM SPSS 29) with the help of a statistical expert. Pearson's correlation method was used on a newly formed table containing data on total malaria cases, average rainfall, average temperature, ITBN, LLIN, Fogging and IRS, all of them present in a yearly manner from 2014-2022. Pearson's correlation coefficient was calculated for every corresponding pair of factors and their significance level was checked. Later regression analysis was done on the above mentioned data and also regression model was made.

Pearson's correlation method was also used on primary data. The effect of education on knowledge of public regarding malaria and their hygiene conditions in and around home was discovered by calculating the correlation coefficient.

Species type distribution of malaria cases

There were 272 confirmed malaria cases in 7 block PHCs of the Barpeta district during the study period 2014–2022.

Tab 3: Species types distribution of malaria cases in Barpeta district from 2014 to 2022

Year	*Pv*	*Pf*	Mixed	Total Cases
2014	42	55	3	98
2015	32	43	0	75
2016	33	20	0	53
2017	15	3	0	18
2018	9	2	0	11
2019	9	1	0	10
2020	1	0	0	1
2021	2	1	0	3
2022	3	0	0	3

where, *Pv – Plasmodium vivax* ; *Pf – Plasmodium falciparum*

The total number of malaria cases decreased from 98 cases in 2014 to 43 cases in 2015 (56.12% reduction). *Pf* accounted for 55 cases in 2014 and 43 cases in 2015 (21.81% reduction). While mixed infection cases decreased from 3 cases in 2014 to 0 cases in 2015 (100% reduction). *Pv* accounted for 42 cases in 2014 and 32 cases in 2015 (23.80 reduction). There was also a great decrease in malaria cases from 75 cases (in 2015) to 53 cases (in 2016) i.e. 29.33% reduction. The *Pf* cases decreased by 53.49% in 2015–2016 from 43 cases to 20 cases. The *Pv* cases on the other hand has increased by 3.13% in 2015– 2016 from 32 cases to 33 cases and no mixed infections can be seen. There was a remarkable decrease of 66.04% in total malaria cases from 2016 (53 cases) to 2017 (18 cases). *Pf* cases dropped from 20 cases in 2016 to 3 cases 2017 (85% reduction). *Pv* cases dropped from 33 cases in 2016 to 15 in 2017 (54.55% reduction) and there were no mixed infection cases. Total malaria cases dropped by 38.89% in 2017–2018 from 18 cases to 11 cases. *Pf* cases dropped from 3 cases in 2017 to 2 cases in 2018 i.e. 33.33% reduction. *Pv* cases dropped from 15 cases in 2017 to 9 cases in 2018 i.e. 40% reduction while no mixed cases were found. There was a slight decrease in total malaria cases by 9.09% from 11 cases in 2018 to 10 cases in 2019. Half time reduction in *Pf* cases can be seen i.e. 50% from two cases in 2018 to 1 case in 2019. The *Pv* cases remain constant i.e. 9 cases in 2018 to 9 cases in 2019 as well and no

mixed infections were reported. Remarkable decrease in total malaria cases by 90% from 10 cases in 2019 to 1 case in 2020. *Pf* cases in 2020 reduced to 0 from 1 case in 2019 (i.e. 100% reduction) and *Pv* cases were seen to decrease by 88.89% from 9 cases in 2019 to 1 case in 2020 and no mixed infection cases were reported. Sudden increase of total malaria cases by 66.67% from 1 case in 2020 to 3 cases in 2021 was marked. *Pf* cases were seen to increase by 1% i.e. from 0 cases in 2020 to 1 case in 2021 and the *Pv* cases increased by 100% i.e. from 1 case in 2020 to 2 cases reported in 2021. There were no mixed infection cases. Total malaria cases remain constant by three cases 2021-2022. Total *Pf* cases were seen to increase by 33.33% from 2 cases in 2021 to 3 cases in 2022 with no mixed infections being reported.

Malariometric Indicators

For all Barpeta district block PHCs, the API indicator (out of 1000 inhabitants under surveillance) showed a gradual decrease from 2014 until 2018 and was found to be 0.06, 0.04, 0.011, 0.006 and then the API indicator showed a slight increase in 2019 and was found to be 0.07 and then again decreased and was found 0.05 and 0.002 for 2020, 2021 respectively. Similarly, the rate indicator i.e. Annual Blood Examination Rate (ABER) was 12.06, 12.05, 11.57, 9.31, 9.009, 10.56, 7.65 and 9.88 for 2014, 2015, 2016, 2017, 2018, 2019, 2020 and 2021 respectively.

Tab 4: Malariometric Indices of Barpeta district from 2014 to 2021

Year		2014	2015	2016	2017	2018	2019	2020	2021
Population		1,658,644	1,662,708	1,668,757	1,677,320	1,681,516	1,688,818	1,724,344	1,744,060
Cases		1,99,990	2,00,438	1,93,067	1,56,102	1,51,490	1,78,410	1,31,948	1,72,317
Malario-metric Indicator	API	0.06	0.04	0.03	0.011	0.006	0.007	0.005	0.002
	ABER	12.06	12.05	11.57	9.31	9.009	10.56	7.65	9.88

where,

API (Annual parasite index) = (Total number of positive slides for parasite in a year×1000)/Total population.

ABER (Annual blood examination rate) = (Smear examination in a year × 100)/Total Population.

Categorization of all blocks according to API (Annual parasite index)

During the study period, i.e. from 2014 to 2022, the malaria prone Barpeta district was seen to recover from this epidemic as fewer cases have been reported every year. According to API, there were no block PHCs under Category 3 and Category 2. In 2014, 2015, and 2016, all the 7 block PHCs were marked under Category 1, which then have recovered from malaria disease. In 2020, Mandia block PHC was placed under Category 0 with 0 malaria cases but the very next year, in 2021 a sudden increase in malaria was reported to and marked Mandia under Category 1. Similarly, Nagaon block PHC was placed in Category 0 in 2017 and then in 2018 it was placed in Category 1 due to high API criteria.

Tab 5: Categorization of blocks in Barpeta district from 2014 to 2021

Category	Year							
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
3	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
2	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
1	Barpeta Road, Bhawanipur, Chenga,Kalgachia, Mandia,Nagaon,Nityananda	Barpeta Road, Bhawanipur, Chenga,Kalgachia, Mandia,Nagaon,Nityananda	Barpeta Road, Bhawanipur, Chenga,Kalgachia, Mandia,Nagaon, Nityananda	Bhawanipur, Chenga,Kalgachia, Mandia,Nityananda	Bhawanipur, Chenga, Kalgachia, Mandia, Nagaon, Nityananda	Bhawanipur, Chenga, Kalgachia, Mandia	Kalgachia	Mandia

0	Nil	Nil	Nil	Barpeta Road, Nagaon	Barpeta Road	Barpeta Road, Nagaon, Nityananda	Barpeta Road, Bhawanipur, Chenga, Mandia, Nagaon, Nityananda	Barpeta Road, Bhawanipur, Chenga,Nagaon,Nityananda

Tab 6: Categorization of blocks in Barpeta district from 2014 to 2021(in numbers)

Year	Category 0	Category 1	Category 2	Category 3	Total
2014	0	7	0	0	7
2015	0	7	0	0	7
2016	0	7	0	0	7
2017	2	5	0	0	7
2018	1	6	0	0	7
2019	3	4	0	0	7
2020	6	1	0	0	7
2021	5	1	0	0	7
2022	7	0	0	0	7

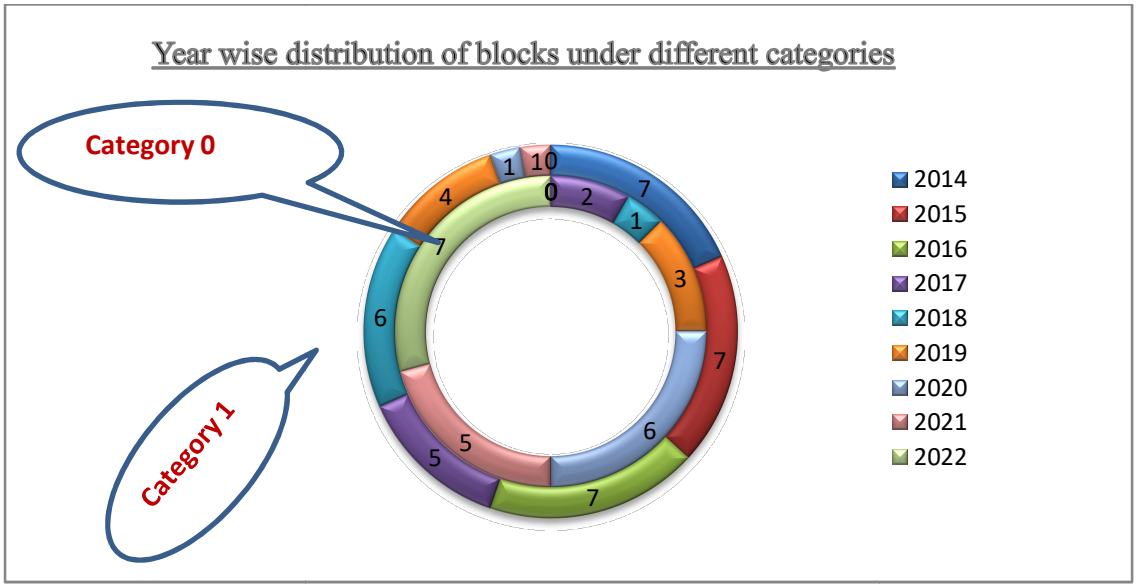

Fig 2: Doughnut chart of distribution of blocks of Barpeta district under different categories (2014-2022)

Demographic summary of malaria cases

During the period 2014-2022, male patients (183 no.s) and female patients (77 no.s) accounted for 70.38% and 29.61% of the total malaria cases respectively. The contribution of male patients to the total malaria cases as compared to female patients is also evident from the column chart below.

Tab 7: Gender-wise distribution of malaria patients in Barpeta district from 2014-2022

Year	Male patients	Female patients	Total Malaria Cases
2014	68	30	98
***2015**	49	22	71
***2016**	30	15	45
2017	11	7	18
2018	8	3	11
2019	10	0	10
2020	1	0	1
2021	3	0	3
2022	3	0	3

*Estimated by linear interpolation method

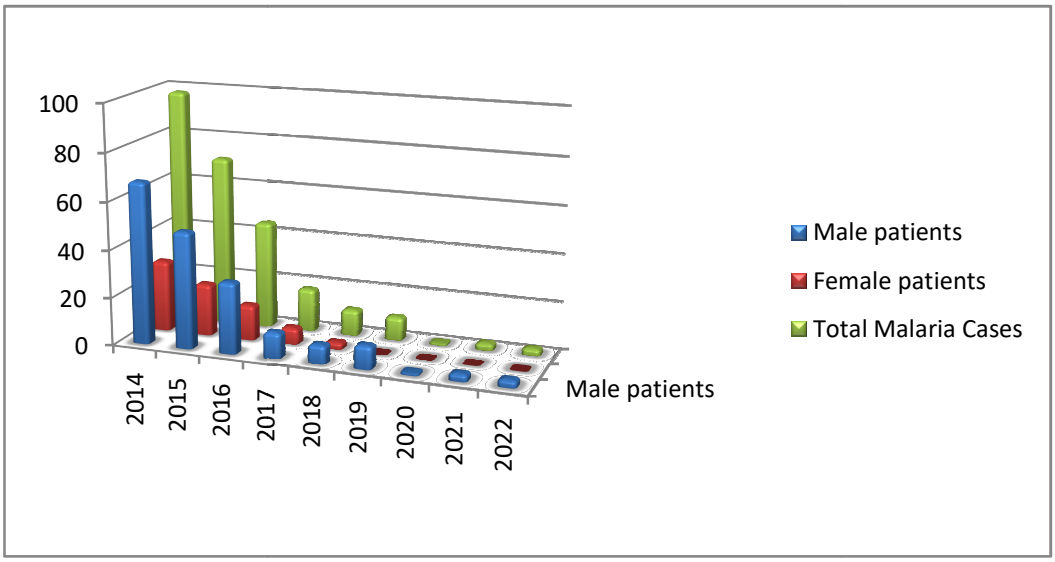

Fig 3: Column Chart of Gender-wise distribution of malaria patients in Barpeta district (2014-2022)

Age wise distribution of malaria cases

It was found that people with the age group of >15 years of age were more prone in causing the disease all throughout the study period irrespective of the gender whereas people <5 years of age are hardly affected by malaria in comparison to the other two age groups.

Tab 8: Age group distribution of malaria cases in Barpeta district (2014-2022)

Age group	2014	*2015	*2016	2017	2018	2019	2020	2021	2022
<5 yrs	0	0	1	1	0	0	0	0	0
5-15 yrs	16	3	3	3	1	2	0	0	0
>15 yrs	32	10	10	14	11	8	1	3	3

*Estimated by linear interpolation method

Malaria IEC activities

From the IEC data, it was seen that not every awareness measure was taken in a particular year. There were no SC level awareness meetings and village level awareness camps after 2019. But school level awareness camps and miking remains consistent happening almost every year. However street play on malaria awareness was staged only twice in the period 2014-22. Although none of the measures proved to significant during correlation method, scatter chart of the same suggests that as compared to other measures, miking has influenced the reducing number of malarial cases over the years.

Tab 9: Malaria IEC activities in Barpeta district (2014-2022)

Year	Sub-centre level awareness meeting	School level awareness camp	Village level awareness camp	Street Play	Miking	Total Malaria Cases
2014	0	28	56	0	26	98
***2015**	70	46	37	0	21	71
***2016**	141	64	19	0	16	45
2017	211	82	0	0	11	18
2018	160	51	118	0	0	11
2019	112	84	0	13	40	10
2020	0	0	0	0	22	1
***2021**	0	25	0	5	18	2
2022	0	50	0	0	13	3

*Estimated by linear interpolation

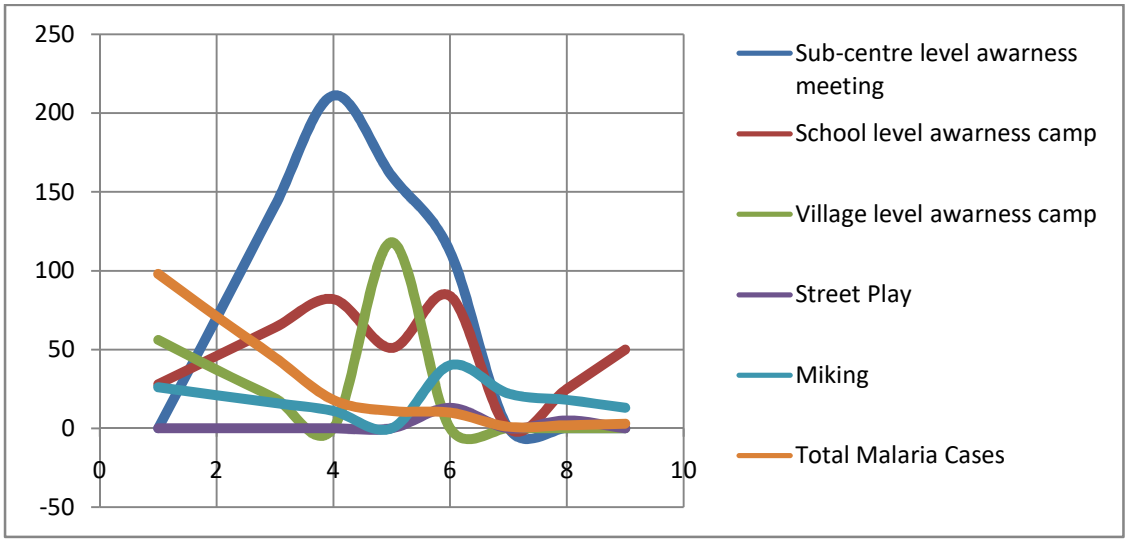

Fig 4: Scatter chart of IEC activities in Barpeta district throughout the study period 2014-2022.

Seasonal variation of malaria cases

Malarial infection varies with season (month), which is evident from table. On a broad view, most malaria cases were registered during July and August, which is the monsoon season (rainy season). But it is seen that in 2020, only one case was registered in the whole year in December. Similarly in 2021, there were only two cases in whole year in October.

Tab 10: Seasonal variation of malaria cases in Barpeta district (2014-2022)

Month	2014	*2015	*2016	2017	2018	2019	2020	2021	2022
January	3	1	1	0	1	0	0	0	0
February	1	0	0	0	0	1	0	0	0
March	3	1	1	0	1	0	0	0	0
April	8	1	1	0	0	1	0	0	0
May	4	1	1	1	1	1	0	0	0
June	21	4	4	6	3	1	0	0	0
July	14	3	3	2	1	2	0	1	0
August	15	3	3	1	2	2	0	0	0
September	6	2	2	0	2	1	0	0	3
October	10	3	3	5	1	0	0	2	0
November	5	1	1	3	0	0	0	0	0
December	5	1	1	0	0	1	1	0	0

*Estimated by linear interpolation method

Other Factors Affecting Malaria

A part of the primary data collected through survey indicates the following – most of the people residing in the most malaria prevalence area of each block fall under economically weaker section; almost 73% of them belongs to muslim community and almost 88% of them belongs to general category on an average; DDT spray was witnessed by the most people in comparison to other control measures.

Tab 11: Survey data (based on income)

Survey area	Block PHC	Economically Weak (EWS) (< 3 lakhs) (%)	Lower Income (LIG) (3-6 lakhs) (%)	Middle Income (MIG) (%)		High Income (HIG) (> 18 lakhs) (%)
				MIG 1 (6-12 lakhs) (%)	MIG 2 (12-18 lakhs) (%)	
Barapetta	Barpeta Road	90	10	0	0	0
Ananda Pur	Bhawanipur	90	0	10	0	0
Gadhersali Pam	Chenga	100	0	0	0	0
Tapeswara	Kalgachia	100	0	0	0	0
Baghbar	Mandia	100	0	0	0	0
Khandakar para	Nagaon	100	0	0	0	0
Singimari	Nityananda	100	0	0	0	0

Tab 12: Survey data (based on religion and caste)

Survey area	Block PHC	Religion (%)		Caste (%)				
		Hinduism	Muslim	General	OBC	SC	ST	Others
Barapetta	Barpeta Road	10	90	90	10	0	0	0
Ananda Pur	Bhawanipur	0	100	100	0	0	0	0
Gadhersali Pam	Chenga	80	20	20	0	0	8	0
Tapeswara	Kalgachia	0	100	100	0	0	0	0
Baghbar	Mandia	0	100	100	0	0	0	0
Khandakar para	Nagaon	0	100	100	0	0	0	0
Singimari	Nityananda	100	0	100	0	0	0	0

Tab 13: Survey data (based on control measures and awareness)

Survey area	Block PHC	Control measures implemented in the past nine years by the authorities (%)			Awareness program experienced (per household) (%)
		Distribution of medicated mosquito nets (per household)	Malathion Fogging (per household)	DDT spraying (per household)	
Barapetta	Barpeta Road	20	0	40	0
Ananda Pur	Bhawanipur	20	0	0	0
Gadhersali Pam	Chenga	60	0	30	20
Tapeswara	Kalgachia	0	0	80	30
Baghbar	Mandia	10	0	10	10
Khandakar para	Nagaon	10	0	20	10
Singimari	Nityananda	0	0	0	0

Results from statistical analysis

The Pearson Correlation between the attributes – (Average rainfall, average temperature, ITBN, LLIN, fogging, IRS) and Total malaria cases year-wise, indicated that only three attributes are significant (at 0.05 level) in determining the total malaria cases per year. The significant factors are – LLIN, fogging, IRS. The fogging showed a negative correlation while the other two showed positive correlation. The LLIN data

showed the strongest relation with the total malaria cases, having a correlation value of 0.784. Apart from these, some other factors were significant (at 0.01 level) but not for the malaria cases. Negative correlation was seen between fogging & temperature (-.805) and IRS & fogging (-.801).

Correlations

		Total malaria cases	Average rainfall (in mm)	Average temperature (in ◦C)	ITBN distributed (no.)	LLIN distributed (no.)	Fogging (No. of villages covered)	IRS (% of population covered)
Total malaria cases	Pearson Correlation		0.145	0.553	-0.179	.784*	-.668*	.682*
	Sig. (2-tailed)		0.709	0.123	0.645	0.012	0.049	0.043
Average rainfall (in mm)	Pearson Correlation			0.136	0.171	0.026	-0.482	0.226
	Sig. (2-tailed)			0.727	0.661	0.947	0.189	0.558
Average temperature (in ◦C)	Pearson Correlation				-.742*	0.53	-.805**	.791*
	Sig. (2-tailed)				0.022	0.143	0.009	0.011
ITBN distributed (no.)	Pearson Correlation					-0.16	0.413	-0.491
	Sig. (2-tailed)					0.681	0.27	0.179
LLIN distributed (no.)	Pearson Correlation						-0.552	0.537
	Sig. (2-tailed)						0.123	0.136
Fogging (No. of villages covered)	Pearson Correlation							-.801**
	Sig. (2-tailed)							0.009

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Fig 5: Statistical analysis: Pearson's Correlation Method (fixed factor-total malaria cases) (as obtained in SPSS software)

The regression model formed from the regression analysis of the table is as follows -

Total Malaria Cases = 13.2072 + 0.0007(LLIN) – 0.0758(fogging) + 0.1960(IRS)

Multiple R-squared: 0.718
Adjusted R-squared: 0.5488
F-statistic: 4.243 on 3 and 5 DF, p-value: 0.0768

The application of the Pearson's correlation method on the primary data revealed that education had a negative effect on the knowledge of causes of malaria, while it had

positive effects on others. Education was most positively related to public knowledge of preventive measures (showing a correlation coefficient of 0.594).

Tab 14: Statistical analysis: Pearson' Correlation Method (fixed factor-literate %)

Block	Knowledge regarding malaria				Hygiene conditions around home(%)	Literate (%)
	Causes (%)	Transmission (%)	Symptoms (%)	Preventive measures (%)		
Barpeta Road	60	20	60	0	40	50
Bhawanipur	50	10	80	20	30	70
Chenga	90	30	100	60	70	60
Kalgachia	70	50	90	40	100	80
Mandia	80	10	100	40	70	40
Nagaon	90	40	80	60	30	80
Nityananda	70	0	100	90	90	90
Correlation coefficient (with Literate %)	-0.02653	0.183824	0.15035419	0.59490852	0.2364763	

Of the 70 household surveys done, most of the respondents knew about the causes of malaria i.e. 72.86%. Almost all the respondents knew about the symptoms of malaria i.e. 87.14%. But surprisingly very less people knew about the transmission of malaria through mosquito bites i.e. 22.86%. Almost 61.43% of the people had kept their surroundings clean but none of the respondents amongst the household surveys done in Barpeta Road Block PHC knew about the preventive measures and only 28.57% people of the Bhawanipur Block PHC knew about the measures that should be taken to prevent malaria. It was good to see that 100% of the people of the Kalgachia Block PHC have maintained a proper hygiene around their houses to prevent the occurrence of different diseases.

Initially around 2014, 2015, 2016, *Pf* caused more malaria as compared to *Pv*. But gradually malaria cases started to decrease. This decline in cases was mainly due to reduced Pf infection. New drugs for malaria were introduced in 2013 and they have been same since then. So it can be assumed that the new drugs had more effects against *Pf* than *Pv*. The decrease in API itself explains the reduction of malaria cases. API in blocks of Barpeta district remained in Category 1 till 2016. From 2017 onwards blocks started to fall under category 0 but Kalgachia block and Mandia block stayed under category 1 for a long time. The conclusion that can be drawn from this is that the parasite control in those blocks was not effective or not followed properly compared to other blocks. The reduced API index, if not maintained may result in re-occurrence of malaria or other vector diseases. Following the declining trend of malarial infection, ABER should have shown a increasing trend. But it showed a declining trend although the rate was high around 2019. This may have been the result of increasing awareness among the public. The more number of male malaria patients make sense as they are more exposed to the outside environment than female and many a times the occupation site becomes the reason for more male patients. Similarly, people with age more than 15 yrs, contributing the most to total malaria cases than other age groups makes sense. Usually in a family, person with age less than 5 yrs and within 5-15 yrs are more taken care of by the adults but the vive-versa is rare. So the adults are more prone to the disease. The male adults therefore should be aware and taken care of to prevent malaria and also like-diseases. Although no awareness measure turned out to be significant in reducing the malarial infection, but its effects cannot be mere. It was the awareness of the public due to which they approached the medical authority and this way the authorities were able to raise ideas by interacting with them as to on how to deal with the disease. An important discussion would be a discussion on the seasonal variation of malaria cases because of its relation with the primary host of *Plasmodium* i.e. female anopheles mosquito. Mosquitoes breed mainly on stagnant water and this is common in monsoon season. Also the cases were maximum in this season. So it is vital, at present also, to make the surroundings hygiene specially during this season even though malaria cases are rare now-a-days. Low temperature makes the malaria transmission slow and chances of infection are low. But both rainfall and temperature have less or no impact on the declining trend of malaria cases.

It was known from the survey that the most affected areas in the past nine years has families with mostly annual income of <3lakhs. Better financial condition means better facilities (use of proper mosquito nets, proper surroundings with no chance of stagnant water, proper house, proper clothing etc.). It can be said that if the financial conditions become better, there will be no malaria cases (zero level) and there will be lesser chances of getting other infections or diseases. Survey data showed that the control measures and awareness programs were not received by all the households in the same area. This means improper implementation of control measures and awareness programs by the authority. This arises a doubt that if the implementations were proper, the elimination of malaria would have occured years before. Education plays an important role in the public awareness. The topic of malaria is included at almost every

level of education at specific knowledge level. So we can say along with the awareness from the authorities and other factors, education has played an important role in the reduction of malaria.

Limitations of the Study

- Limited Data Access – A larger data size means a better study. Secondary data regarding malaria was not available from before 2014 due to lack of infrastructure for data storage at the office. So, the study had to be done using data available of only nine years (i.e. 2014-2022). Moreover certain data for few years were missing even from these studied years. To perform analysis, the missing data were estimated by linear interpolation method.
- Small sample size – The sample size considered for the survey in the project is small because of limited time and limited accessibility to every parts of the study area. Considering a larger sample size in future, will fetch more accurate results.
- Limited time – Time has evolved as a mere but mentionable limitation specially in the survey part of the project.

CONCLUSION

In conclusion, it is the first comprehensive study in Barpeta district, Assam, India, demonstrating the factors influencing malaria cases. LLINs distribution has proved to put a major impact in significantly reducing the number of malaria cases. Also, expansion of improved health educational content has proved to put a massive impact in maintaining a healthy lifestyle, which has led to the reduction of diseased cases. However, the study didn't show any significant statistical association of malaria with the climatic factors i.e. rainfall and temperature. Though the malaria cases have decreased to a great extent, but it has not completely eradicated. Continuation of LLINs distribution along with proper implementation of IEC activities will further decrease the cases and eventually eradicate malaria from entire Barpeta district, making it a malaria free district, which is still a millennial goal to achieve in the context of current status.

Our study will cite an example to the government authorities of other states to create a data driven malaria predictor and moving ahead with well planned Knowledge, awareness, practices (KAP) surveys (which we are planning ahead to do so) to avoid reappearance of malaria cases and to sustain eradication goals in eventually making the entire nation malaria free. This research is also expected to facilitate control and prevention of other vector-borne diseases, by conductance of same type of research in case of other diseases.

BIBLIOGRAPHY

i. Ahmed, R.A., Shankar, H., Hussain, S.S.A., Swargiary, A., Kumar, A., Tarique, M., Prabhakar, P., Suri, H.S., Singh, K., Chakma, J.K., Singh, J., & Begum, A. (2022). Moderate Rainfall and High Humidity During the Monsoon Season, Negligence in Using Malaria Protection Methods and High Proportion of Mild Symptomatic Patients Were the Driving Forces for Upsurge of Malaria Cases in 2018 Among Tea Tribe Populations in Endemic Dolonibasti Health Sub-center, Udalguri District, Assam State, North-East India. *Frontiers in medicine*, 9, 913848. https://doi.org/10.3389/fmed.2022.913848

ii. Chilot, D., Mondelaers, A., Alem, A.Z., Asres, M.S., Yimer, M.A., Toni, A.T., Ayele, T.A. (2023). Pooled prevalence and risk factors of malaria among children aged 6-59 months in 13 sub-Saharan African countries: A multilevel analysis using recent malaria indicator surveys. *PLOS ONE*, 18(5). https://doi.org/10.1371/journal.pone.0285265

iii. Dhiman, S. (2019). Are malaria elimination efforts on right track? An analysis of gains achieved and challenges ahead. *Infectious Diseases of Poverty,* 8(14). https://doi.org/10.1186/s40249-019-0524-x

iv. Kumar, S., Srivastava, D.K., Jaiswal, K., Shukla, S.K., Bajpai, P.K., & Kaushik, A. (2022). Assessment of knowledge and their practices regarding malaria among members of Village Health Sanitation Committee in rural Uttar Pradesh: A cross-sectional study. *Journal of Family Medicine and Primary Care*, 11(2), 573-580. https://doi.org/10.4103/jfmpc.jfmpc_1235_21

v. Kumar, V., Mangal, A., Panesar, S., Yadav, G., Talwar, R., Raut, D., & Singh, S. (2014). Forecasting Malaria Cases Using Climatic Factors in Delhi, India: A Time Series Analysis. *Malaria Research and Treatment,* 2014(482851). https://doi.org/10.1155/2014/482851

vi. National Vector Borne Disease Control Programme: NVBDCP Report (2020).

vii. Okell, L.C., Drakeley, C.J., Ghani, A.C., Bousema, T., & Sutherland, C.J. (2008). Reduction of transmission from malaria patients by artemisinin combination therapies: a pooled analysis of six randomized trials. *Malaria Journal,* 7(125). https://doi.org/10.1186/1475-2875-7-125

viii. Pradhan, S., Hore, S., Maji, S.K., Manna, S., Maity, A., Kundu, P.K., Maity, K., Roy, S., Mitra, S., Dam, P., Mondal, R., Ghorai, S., Jawed, J.J., Dutta, S., Das, S., Mandal, S., Mandal, S., Kati, A., Sinha, S., Maity, A.B., Dolai, T.K., Mandal, A.K., & Ince, I.A. (2022). Study of epidemiological behaviour of malaria and its control in the Purulia district of West Bengal, India (2016-2020). *Scientific Reports,* 12(630). https://doi.org/10.1038/s41598-021-04399-x

ix. Rabha, B., Goswami, D., Dhiman, S., Das, N.G., Talukdar, P.K., & Singh, L. (2012). A cross sectional investigation of malaria epidemiology among seven tea estates in Assam, India. *Journal of parasitic diseases: official organ of the Indian Society for Parasitology*, 36(1), 1-6. https://doi.org/10.1007/s12639-011-0070-3

x. Ranjha, R., & Sharma, A. (2021). Forest malaria: the prevailing obstacle for malaria control and elimination in India. *BMJ Global Health,* 6(5). https://doi.org/10.1136/bmjgh-2021-005391

xi. Sarkar, R., Kessler, A., Mawkhlieng, B., Sullivan, S.A., Wilson, M.L., Carlton, J.M., & Albert, S. (2021). Household and individual level risk factors associated with declining malaria incidence in Meghalaya, India: implications for malaria elimination in low-endemic settings. *Malaria Journal,* 20(460). https://doi.org/10.1186/s12936-021-03982-x

xii. Sarma, D.K., Mohapatra, P.K., Bhattacharyya, D.R., Chellappan, S., Karuppusamy, B., Barman, K., Kumar, N.S., Dash, A.P., Prakash, A., & Nina, P.B. (2019). Malaria in North-East India: Importance and Implications in the Era of Elimination. *Microorganisms*, 7(12), 673. https://doi.org/10.3390/microorganisms7120673

xiii. Sharma, R.K., Thakor, H.G., Saha, K.B., Sonal, G.S., Dhariwal, A.C., & Singh, N. (2015). Malaria situation in India with special reference to tribal areas. *The Indian Journal of Medical Research*, 141(5), 537-545. https://doi.org/10.4103/0971-5916.159510

xiv. Sirimatayanant, M., Hein, P.S., Anderson, L.F., Montoya, L.F., Potter, R., Nghipumbwa, M., Ranaweera, P., Ngor, P., Phetsouvanh, R., & Maude, R.J. (2023). Gaps in research and capacity development for malaria surveillance and response in the Asia-Pacific: meeting report. *Malaria Journal,* 22(91). https://doi.org/10.1186/s12936-023-04459-9

xv. Tesfa, H., Bayih, A.G., & Zeleke, J. (2018). A 17-year trend analysis of malaria at Adi Arkay, north Gondar zone, Northwest Ethiopia. *Malaria Journal,* 17(155). https://doi.org/10.1186/s12936-018-2310-9

xvi. Wang, C., Thakuri, B., Roy, A.K., Mondal, N., Qi, Y., & Chakraborty, A. (2023). Changes in the associations between malaria incidence and climatic factors across malaria endemic countries in Africa and Asia-Pacific region. *Journal of Environmental Management,* 331. https://doi.org/10.1016/j.jenvman.2023.117264

xvii. Wang, L., Yin, J., Zheng, C., Smith, S.J., Ngegba, E., Huang, X., Kamara, A., Chen, X., Wang, X., Luo, W., & Kan, B. (2021). A Household-Based Cross-Sectional Survey of Knowledge, Awareness and Practice Regarding Malaria in Western Area Rural District, Sierra Leone. *Front. Public Health*, 9(664971). https://doi.org/10.3389/fpubh.2021.664971

xviii. Yadav, K., Dhiman, S., Rabha, B., Saikia, P.K., & Veer, V. (2014). Socio-economic determinants for malaria transmission risk in an endemic primary health centre in Assam, India. *Infectious Diseases of Poverty*, 3(19). https://doi.org/10.1186/2049-9957-3-19

xix. https://barpeta.assam.gov.in/about-us-level-two/geography/about-barpeta (accessed 11 March, 2023).

xx. https://m.timesofindia.com/city/guwahati/assam-records-declining-malaria-numbers/amp_articleshow/58370850.cms (accessed 23 July, 2023).

xxi. https://www.indiacensus.net/district/barpeta (accessed 11 March, 2023).

xxii. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1677601#:~:text=Malaria%20has%20been%20made%20notifiable,Nadu%2C%20Telangana%2C%20Tripura%20Uttar%20Pradesh (accessed 23 July, 2023)
xxiii. https://www.researchgate.net/figure/Location-map-of-Barpeta-District-For-this-study-flood-damage-data-were-collected-from_fig1_319980137 (accessed 26 March, 2023).
xxiv. https://www.theglobalfund.org/en/ (accessed 10 August, 2023)

Tab 15: Year-wise epidemiological data of malaria (2014-2022)

Year	PHC	Population	Total Fever Cases	RDT done	RDT +ve	BSC		Total Malaria	Total Pf	Pf%	Death
						Examination	+ve				
2014	Barpetaroad	135537	22997	1727	0	21270	7	7	3	42.86	-
	Bhawanipur	247972	30461	1280	3	29181	26	29	9	31.03	-
	Chenga	243633	32058	454	10	31604	5	15	12	80	-
	Kalgachia	245825	28758	728	4	28030	2	6	4	66.66	-
	Mandia	352992	28369	1355	3	27014	20	26	15	57.69	-
	Nagaon	251915	27791	1090	4	26701	1	3	2	60	-
	Nityananda	201978	29556	354	2	29202	8	12	9	66.66	-
	Dist. Total	**1658644**	**199990**	**6988**	**26**	**193002**	**74**	**98**	**55**	**55**	
2015	Barpetaroad	134145	23264	4988	3	18276	5	8	3	37.5	-
	Bhawanipur	228425	26977	3743	3	23234	3	6	3	50	-
	Chenga	243735	31335	6653	8	24682	0	8	2	25	-
	Kalgachia	246215	28943	4787	4	24156	0	4	1	25	-
	Mandia	253410	33609	7603	30	26006	3	33	25	75.76	-
	Nagaon	252210	26762	8335	8	18427	0	8	7	87.5	-
	Nityananda	204568	29548	8328	8	21220	0	8	2	25	-
	Dist. Total	**1662708**	**200438**	**44437**	**64**	**156001**	**11**	**75**	**43**	**57.33**	
2016	Barpetaroad	136257	21375	3218	3	18157	1	4	2	50	-
	Bhawanipur	230576	24776	5735	11	19041	0	11	5	45.45	-
	Chenga	245467	25855	3968	8	21887	2	10	2	20	-
	Kalgachia	248823	30125	6637	2	23488	0	2	0	0	-
	Mandia	355636	35740	7484	16	28256	6	22	8	36.36	-
	Nagaon	253838	22279	3874	2	18405	0	2	2	100	-
	Nityananda	206727	32917	7138	0	25779	2	2	1	50	-
	Dist. Total	**1668757**	**193067**	**38054**	**42**	**155013**	**11**	**53**	**20**	**37.73**	
2017	Barpetaroad	136256	13806	1491	0	12315	0	0	0	-	-

	Bhawanipur	230576	23365	9901	5	13464	0	5	1	20	-
	Chenga	245467	28545	10228	2	18317	0	2	2	100	-
	Kalgachia	248823	25762	6705	2	19057	0	2	0	-	-
	Mandia	355633	26031	8532	7	17499	0	7	-	-	-
	Nagaon	253838	17198	5840	0	11358	0	0	-	-	-
	Nityananda	206727	21395	4872	2	16523	0	2	-	-	-
	Dist. Total	**1677320**	**156102**	**47569**	**18**	**108533**	**0**	**18**	**3**	**16.67**	
2018	Barpetaroad	136599	277386	1491	-	8233	-	0	0	0	-
	Bhawanipur	231153	272618	6067	-	19326	-	4	1	25	-
	Chenga	246081	31305	9621	-	21684	-	2	0	0	-
	Kalgachia	249445	20923	4343	-	16580	-	1	0	0	-
	Mandia	356522	25498	6520	-	18978	-	2	0	0	-
	Nagaon	254472	18146	4403	-	13743	-	1	0	0	-
	Nityananda	207244	20501	4302	-	16199	-	1	1	100	-
	Dist. Total	**1681516**	**151490**	**36747**		**114743**		**11**	**2**	**18.18**	
2019	Barpetaroad	137282	270368	3944	-	8605	-	0	0	0	-
	Bhawanipur	231846	227745	10626	-	17592	-	1	0	0	-
	Chenga	247586	33405	10057	-	23348	-	1	0	0	-
	Kalgachia	250747	25705	11938	-	13767	-	5	0	0	-
	Mandia	357592	30264	15670	-	14594	-	3	1	33.33	1
	Nagaon	255490	20608	8213	-	12395	-	0	0	0	-
	Nityananda	208280	27661	9175	-	18486	-	0	0	0	-
	Dist. Total	**1688818**	**178410**	**69623**		**108787**		**10**	**1**	**8.33**	
2020	Barpetaroad	137878	382020	10035	-	967	-	0	0	0	-
	Bhawanipur	232176	407650	14702	-	6095	-	0	0	0	-
	Chenga	241758	24590	20072	-	4518	-	0	0	0	-
	Kalgachia	287898	20954	17677	-	3277	-	1	1	100	-
	Mandia	358317	21003	18732	-	2271	-	0	0	0	-
	Nagaon	256709	16735	14350	-	2385	-	0	0	0	-

	Nityananda	209608	16867	14057	-	2810	-	0	0	0	-
	Dist. Total	**1724344**	**131948**	**109625**		**22323**		**1**	**0**	**0**	
2021	Barpetaroad	138614	272618	11659	-	3546	-	0	0	0	-
	Bhawanipur	246930	26365	19481	-	6884	-	0	0	0	-
	Chenga	245649	26601	21432	-	5169	-	0	0	0	-
	Kalgachia	290852	30025	28089	-	1936	-	0	0	0	-
	Mandia	360306	28851	25833	-	3018	-	3	1	33.33	-
	Nagaon	257107	22224	14354	-	7870	-	0	0	0	-
	Nityananda	204602	23046	18406	-	4640	-	0	0	0	-
	Dist. Total	**1744060**	**172317**	**139254**		**33063**		**3**	**1**	**33.33**	
2022	Barpetaroad	141,159	1149	1149	-	1149	-	0	-	-	
	Bhawanipur	250086	1861	1799	-	1861	-	0	-	-	
	Chenga	247306	1308	1308	-	1308	-	0	-	-	
	Kalgachia	295129	1677	1677	-	1677	-	3	-	-	
	Mandia	362689	1591	1591	-	1591	-	0	-	-	
	Nagaon	258,508	1847	1295	-	1847	-	0	-	-	
	Nityananda	206430	2117	1872	-	2117	-	0	-	-	
	Dist. Total	**3,505,367**	**183867**	**149945**	**0**	**44613**		**3**	**0**	**0**	

Tab 16: Year-wise rainfall data (in mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	7.8	30.4	8.84	30.6	226.2	636.6	445.5	610	768.56	61.6	20.1	0.2
2015	16.2	21.3	72.48	286	365.6	1170	931.4	1211.8	511.13	79.83	22.1	13.5
2016	41.2	6.8	45.64	239	509.8	561.9	607.3	258.76	452.26	267.3	4.4	6.1
2017	11.1	25.72	119.5	459	323.4	871.9	891	907.5	674.5	368.2	8.1	0.6
2018	4.5	15	16.12	142	411.8	492.1	571.3	386.2	403.51	65.62	14.5	33.6
2019	8.5	51.8	42.2	145	511.3	452	1175	338.1	393.6	88.8	8.6	1.6
2020	10.7	27.1	7.7	230	851.4	1053	1208	592.5	860.3	215.4	2.7	0.9
2021	4.9	0.6	18.1	71.5	357.7	738.9	672.8	676.1	86.3	70.5	0.5	0.1
2022	6.5	10.2	4.6	94.4	104.7	353.1	94.2	65.6	76.3	66	0.1	0

Tab 17: Year- wise temperature data (in ºC)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	21	24	30	35	33	32	32	30	30	28	25	21
2015	22	26	29	29	32	30	30	30	29	29	25	21
2016	21	26	31	31	31	31	30	32	30	29	26	23
2017	23	26	27	29	31	31	30	31	30	28	26	24
2018	22	25	30	31	30	32	32	32	31	28	25	22
2019	22	24	28	31	30	32	30	32	29	27	26	21
2020	20	23	29	31	29	29	28	30	28	29	24	22
2021	22	26	31	34	29	30	28	28	29	28	24	22
2022	21	21	31	28	29	27	30	29	29	26	24	22

Tab 18: Survey data (based on education)

Survey area	Block PHC	Illiterate (%)	Primary Education (%)	Secondary Education (%)	Higher Secondary or Higher Education (%)
Barapetta	Barpetaroad	50	20	20	10
Ananda Pur	Bhawanipur	30	20	40	10
Gadhersali Pam	Chenga	40	30	30	0
Tapeswara	Kalgachia	20	0	40	40
Baghbar	Mandia	60	10	10	20
Khandakar para	Nagaon	20	30	10	40
Singimari	Nityananda	10	0	40	50

APPENDIX D

CONSENT FORM

1. I volunteer to take part in this questionnaire survey conducted for the research project entitled "A comprehensive study on reduced prevalence of malaria from 2014 to 2022 in Barpeta district, Assam, India."
   ("ভাৰতৰ অসমৰ বৰপেটা জিলাত ২০১৪ চনৰ পৰা ২০২২ চনলৈ মেলেৰিয়াৰ প্ৰাদুৰ্ভাৱ হ্ৰাস পোৱাৰ এক বিস্তৃত অধ্যয়ন" শীৰ্ষক গৱেষণা প্ৰকল্পৰ বাবে কৰা এই প্ৰশ্নাৱলী সমীক্ষাত মই স্বেচ্ছাই অংশগ্ৰহণ কৰোঁ।)

2. I understand that this research has been approved by Research Cell, B.H. College, Howly.
   (মই বুজিপাইছো যে এই গৱেষণাটো গৱেষণা কোষ, বি.এইচ. মহাবিদ্যালয়, হাউলিৰ দ্বাৰা অনুমোদিত হৈছে।)

3. I understand that the information provided by me will only be used in research and analysis purposes. The information will remain completely confidential, only those directly involved with this project will have access to the data.
   (মই বুজি পাওঁ যে মোৰ দ্বাৰা প্ৰদান কৰা তথ্যকেৱল গৱেষণা আৰু বিশ্লেষণৰ উদ্দেশ্যত হে ব্যৱহাৰ কৰা হ'ব। তথ্যটো সম্পূৰ্ণগোপনীয় হৈ থাকিব, কেৱল এই প্ৰকল্পটোৰ সৈতে পোনপটীয়াকৈ জড়িত সকলেহে তথ্যপ্ৰাপ্ত কৰিব।)

4. I understand the summary of the research project and any questions from my side has been answered to my satisfaction.
   (মই গৱেষণা প্ৰকল্পটোৰ সাৰাংশ বুজি পাওঁ আৰু মোৰ ফালৰ যিকোনো প্ৰশ্নৰ উত্তৰ মোৰ সন্তুষ্টিৰ বাবে দিয়া হৈছে।)

Date: _____ **Signature/Thumb impression**: _____

APPENDIX E

SURVEY QUESTIONNAIRE

1. Name of the respondent: …….....

2. Education qualifications:
   □ Illiterate □ Primary □ Secondary □ Higher Secondary or Higher

3. Religion: …… Caste: ……

4. Annual income:

□ Less than 3 lakhs □ 3-6 lakhs □ 6-12 lakhs □ 12-18 lakhs □ More than 18 lakhs

5. Do the respondent know about malaria?
   □ Causes □ Transmission □ Symptoms □ Preventive measures

6. Have the respondent's family maintained hygiene conditions in and around home? ……..

7. Has any member of the respondent's family been infected with malaria in the past nine years (2014-22)? ……..

8. Is the respondent aware of the diagnosis protocols and treatment guidelines? ……..

9. Were control measures implemented in the respondent's residential area by the authorities in the past nine years (2014-22)?

□ Distribution of medicated mosquito nets □ Malathion fogging □ DDT spraying

10. Were awareness programs held in the respondent's residential area by the authorities in the past nine years (2014-22)? ……..

- Location of survey: …….....
- Block PHC: ……..

Fig 6: Visit to District Malaria Office, Barpeta by the investigators.

Fig 7: Glimpses of visit to different block PHCs by principal investigator and co-investigator.

Fig 8: Photos taken during household survey in different villages.