DEPARTMENT OF HEALTH & FAMILY WELFARE
GOVERNMENT OF ODISHA

ODISHA TECHNICAL & MANAGEMENT SUPPORT TEAM: PHASE II

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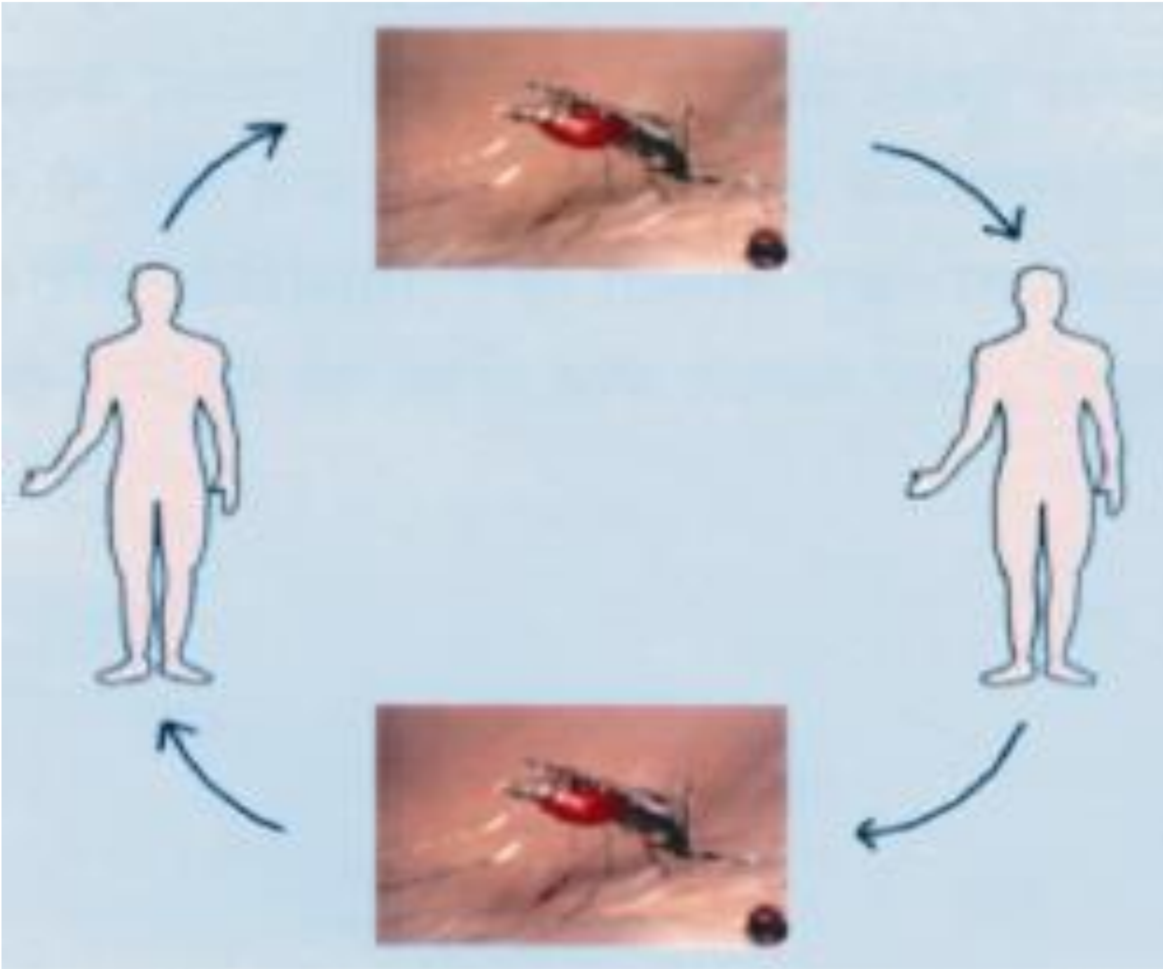

A Paper on how Odisha is positioned for malaria control, based on epidemiological analysis of secondary data and taking into account historical perspectives on control and eradication in the state, as well as current trends

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ABBREVIATIONS AND ACRONYMS	
ABER	Annual Blood Examination Rate
ACT	Artemisinin-Based Combination Therapy
AIDS	Acquired Immuno Deficiency Syndrome
AMI	Annual Malaria Incidence
API	Annual Parasite Index
AR	Auto-Regression
ASHA	Accredited Social Health Activist
BCC	Behaviour Change Communication
CI	Confidence Interval
DDC	Drug Distribution Centre
DFID	Department for International Development, Govt. of UK
DDT	Dichloro Diphenyl Trichloroethane
EDPT	Early Diagnosis and Prompt Treatment
EMCP	Enhanced Malaria Control Project
FTD	Fever Treatment Depot
GFATM	The Global Fund to fight AIDS, Tuberculosis And Malaria
HIV	Human Immuno-Deficiency Virus
IMCP	Intensified Malaria Control Programme
IRS	Indoor Residual Spray
ITN	Insecticide Treated Bed-Nets
IVM	Integrated Vector Management
HSS	Health Systems Strengthening
LLIN	Long Lasting Insecticidal Net
LQAS	Lot quality Assurance Sampling
MA	Moving Averages
M & E	Monitoring And Evaluation
MIS	Management Information System

MMV	Medicines for Malaria Venture
MPO	Modified Plan Of Operation
NMCP	National Malaria Control Programme
NMEP	National Malaria Eradication Programme
NVBDCP	National Vector Borne Disease Control Program
OHSNP	Odisha Health Sector and Nutrition Support Plan
PfCP	Plasmodium falciparum Containment Programme
PHC	Primary Health Centre
RDT	Rapid Diagnostic Test
SARIMA	Seasonal Autoregressive Integrated Moving Averages

Table of Contents

EXECUTIVE SUMMARY

Background

Malaria remains one of the most important causes of human morbidity and mortality in India. An estimated 1.5 million cases and 1000 deaths are officially reported annually in this country as of 20105

Since the inception of the National Malaria Control Programme (NMCP) in 1953, India has continued its battle against malaria through various anti-malaria programs. The country witnessed many rises and sharp falls in malaria burden, such as reaching the brink of malaria elimination in the year 1966 from its very high burden in pre-independence era; and then losing the reins over the disease and experiencing a rapid resurgence leading to extensive malaria outbreaks across the country, which reached its peak in 1976 with 6.47 million cases and 59 reported deaths.

National programmatic initiatives continued thereafter with various new strategies being included periodically in the anti-malaria approaches, putative among which are integrated vector control and intensification of surveillance, monitoring and supervision and inter-sectoral convergence up to2010. Newer approaches were introduced in the later part of last decade in the form of promotion of use of insecticide-treated bed nets, use of rapid diagnostic test kits and introduction of Artemisinin Combination Therapy (ACT). Many such initiatives were supported by multilateral agencies such as World Bank financing the Enhanced Malaria Control Project in 1997 to 2005 and subsequently through a broader vector control programme; and The Global Fund to Fight AIDS, TB and Malaria (GFATM) supporting Intensified Malaria Control Programme in 2005. Bilateral support to some high malaria-endemic Indian states, for example Odisha, was also extended by agencies such as Department for International Development (DFID) of Government of United Kingdom through Orissa Health Sector and Nutrition Support Plan (OHSNP).

Various reports show that, in the last decade, India has made good progress in controlling the disease witnessing a declining trend in overall endemicity of malaria. According to the estimates by NVBDCP from 2001 to 2012, the country recorded a decrease in cases from 2.08 million to 1.06 million, while the malaria deaths have come down from 1005 to 519 during the same period. This declining trend of malaria in India has been attributed to the positive political will and paradigm shift in national malaria control strategy and technical and financial inputs from various national and international sources.

Odisha, an eastern Indian coastal state, occupying only 4% of land mass and 3% of national population, contributed about 27 % of total malaria incidence and approximately 18 % of reported deaths in the country in year 2013, making it the highest contributor to national malaria burden. Over the last decade, Odisha has drawn national and international attention and has intensified anti-malaria activities in line with national initiatives. This initiative is intended to study the epidemiology of malaria in the state with exclusive focus on its temporal and spatial distribution over the last 11 years, thereby helping in the characterization of the disease trends in Odisha; which will be indicative of the effectiveness of the anti-malarial measures implemented over this period, and help predict trends.

Methods

Secondary data was collected from the repository of NVBDCP of Odisha. The data used in the analysis comprised mainly of blood samples examined from malaria suspects and confirmed malaria cases reported during 11 years between 2003 and 2013; these data were collected district-wise and month-wise.

Blood examination and malaria incidence rates were annualized for more convenient comparisons with programmatic benchmarks, month-wise state data were compiled as time-series and trends estimated using generalized least square regression, accounting for serial dependence in time-series data. Additional analyses were done for two periods, 2003 to 2008 and 2009 to 2013. Districts were clustered as per their baseline malaria incidence in 2003 into Very High (API >10 per 1000 population), High (API 5-10 per 1000 population), Moderate (API 2-5 per 1000 population) and Low (<2 per 1000 population). Trends were estimated for individual clusters of districts.

All incidence trends were adjusted for blood examination rate which is a key operational indicator of surveillance, and historic data were used to predict trends for 2014 to 2017 applying Holt-Winters method. Maps were used to thematically examine the progress of the individual districts of Odisha with regard to their malaria endemicity.

Results

During the eleven years (2003-2013), the annual malaria incidence of Odisha has come down from 10.82 per thousand population in 2003 to 5.28 in 2013 whereas the annual blood examination rate (ABER) has almost remained unchanged from 11.25% in 2003 to 11.77% in 2013. The ABER is consistently above the minimum standard for effective surveillance, which, as per the national programme is 10%.

Regarding the trends of pooled data in the same period, there was a significant annual decline in malaria incidence with a linear trend of -0.49 per thousand population (95% CI: -0.60 to -0.37) which got heightened to -0.54 (95% CI: -0.78 to -0.30) after adjustment for blood examination rate. In contrast to this, the blood examination rate underwent hardly any change with the annual decline estimated to be -0.02 percentage points (95% CI: -0.12 to 0.08) over the same period in the state.

The highest peak of this seasonal disease in almost all the years was observed during July-August showing a 41% increase of incidence from the annual mean and the minimum malaria incidence was observed during January, which is 25% less than the annual mean incidence.

In spite of a surge of case detection in 2010, the decline of malaria incidence in the period from 2009 to 2013 was steeper than that observed during 2003 to 2008, the two adjusted trend estimates being -0.83 (95% CI: -1.30 to -0.37) and -0.57 (95% CI: -0.77 to -0.37) respectively. However, 2012 onwards, the decline in incidence seems to be a slowing from the trend graphs.

The cluster-wise decline of malaria incidence was proportionate to baseline disease burden; the absolute decline being most remarkable in the Very High burden districts cluster and being most insignificant in Low burden districts. The 7 southern districts of Odisha (Kandhamal, Kalahandi, Rayagada, Koraput, Nawarangpur, Nuapada and Malkangiri) and two central districts (Sambalpur and Deogarh) continue to be in the Very High endemic zone over the last 11 years.

The prediction for 2014 to 2016 has taken into consideration the slight slowing of the decline experienced from 2012 onwards.

Discussion

Malaria continues to be a public health challenge in Odisha. Under the aegis of NVBDCP, through adoption of different malaria control strategies, this state has continued its fight against the disease. The present study revealed that the state has achieved an average decline of approximately 5% every year from its annual malaria incidence in 2003. This decline was achieved with a steady blood examination rate (above the national standard of 10%) being maintained over this period.

The average annual decline in malaria incidence during the period between 2009 and 2013 was steeper than that was achieved between 2003 and 2008, in spite of an increase in case detection in the early half of 2010. This surge in 2010 malaria case detection by NVBDCP can be partly attributed to the intensification of the anti-malaria activities which started from 2007-08. Introduction of new interventions such as wider coverage of rapid diagnostic test kits and Artemisinin-based combination therapy; distribution of Long Lasting Insecticidal Nets (LLINs); deployment of trained Accredited Social Health Activists (ASHA) and Male Health Workers in malaria control; insecticide residual spraying and other vector control methods; incorporation of modern concepts in surveillance, monitoring and evaluation in malaria control; along with behaviour change communication(BCC) expedited wider coverage by the anti-malaria programme in the state. The underlying drivers of these heightened activities were strong political and administrative commitment, multiple stakeholder involvement and technical and financial support by multilateral and bilateral agencies such as GFATM., World Bank, and DFID.

As a result, intervention measures intensified resulting in surge in blood examination and malaria case reporting in 2010.

This was followed by a sharp decline which could be partly attributable to the preceding rise in case detection through early diagnosis using RDT and effective treatment using ACT at community level of a large number of cases over a short period of time, thereby perhaps reducing the pool of malaria parasite reservoir in the community and interrupting transmission of the disease through wide-spread use of insecticide-treated bed nets during this period.

It was seen that, the absolute decline of malaria incidence was proportionately higher in the cluster of districts with higher disease burden in 2003 and the decline was not significant in the cluster with Low endemicity as there was less malaria burden at baseline in those districts. Again, it is also likely to be due to differential and targeted allocation of resources in the districts as per their endemicity and because new programmatic measures were perhaps initiated in the areas where they were needed most and then scaled-up in other areas.

The sharp decline in the latter half of 2010 and in 2011 slowed down in 2012 and 2013 which was reflected in the prediction for the next three years of 2014 to 2017, thus raising the concerns for possible slowing of the success achieved, as was historically experienced by the country in the sixties. From the prediction model, the goal of achieving annual malaria incidence of <1/1000 seems unlikely by 2017 for the whole state, with southern seven districts that include Kandhamal, Kalahandi, Rayagada, Koraput, Nawarangpur, Nuapada and Malkangiri continuing to be in the Very High (>10 Annual Malaria Incidence) zone of endemicity consistently though each of these districts achieved remarkable decline from their higher baseline burden.

To conclude, the state has achieved remarkable decline in malaria incidence over the last 11 years, attributable to intensified activities, supported by many bilateral and multi-lateral agencies; but such decline needs to be consolidated and any disease resurgence prevented by continuation of such support for anti-malaria strategies and their translation into ground-level activities in the state.

BACKGROUND

Malaria is one of the major public health concerns in India. India's varied geography, ecological diversity and climatic variability make it an ideal place for malaria vectors to breed and transmit the parasite[1]. The disease which was earlier confined only to rural areas has now taken different forms like urban, industrial, plains and forest malaria[1],thus creating extensive breeding sites for the vectors. Besides this, emergence of new features such as vector resistance to insecticides, shifting of parasitic load towards *P. falciparum,* emergence of resistant parasites[2], etc., have made the malaria burden in India more complex and hard to control. In the year 2012, India contributed about 52% of the total cases out of the 2 million confirmed malaria cases in South- East Asia[3]. Nonetheless, India has witnessed a considerable decline in reported malaria cases and deaths from 1996 onwards - from nearly 3.04 million reported malaria cases and 1010 deaths in 1996 to 0.85 million cases and 519 deaths in 2013[4,5]. However, the actual malaria cases and deaths in the country have been presumed to be often greater than reported [6,7].

According to the projections of World Malaria Report 2013, India is likely to reduce by 2015, its malaria case incidence by 50-75% as compared to 1990, which makes it likely to attain the United Nations' Millennium Development Goal targets on malaria. This progress in the malaria situation in the country can be attributed to several factors, namely increased political commitment; concerted national and international efforts and tremendous expansion in financing through various mechanisms[4,8].

The epidemiology of malaria in India, which comprises 29 states and 7 Union Territories (UTs), is complex and is remarkably varied spatially and temporally[9]. The intra and inter-state diversity in topographic and climatic factors greatly influence the variability in distribution of malarial parasites and their vectors[10]. The north-east, central and eastern states of India are the high malaria transmission zones accounting for nearly 80% of total malaria incidence and deaths reported in the country [11]. Among these, the worst affected state is Odisha[6]. Odisha as a state has been one of the biggest contributors to the national burden of malaria[6]. With only about 4% land area and 3% population of India, Odisha accounted for 26.9 % of malaria cases, 46.7 % of total Plasmodium falciparum cases and about 17.6 % of all reported deaths across the country in 2013[5].

History of malaria burden and changes in program strategies

The study of the history of the malaria problem and the control activities to mitigate it in the country is essential to put the malaria epidemiology in India or any of its states in the right perspective.

In a population of 360 million in 1947, 75 million cases of malaria and 0.8 million deaths were reported in pre-independent India. The National Malaria Control Programme (NMCP) was rolled out in 1953 with an objective of reducing the case load, with focus on Indoor Residual Spray (IRS) in high endemic areas. Cases of malaria came down remarkably quickly to 2 million in 1957.

In 1958, the National Malaria Eradication Programme (NMEP) was launched, with the objectives of ending malaria transmission and elimination of reservoir of infection, with enhanced active surveillance and IRS with DDT (attack phase). NMEP brought in further rapid fall in malaria burden - by 1965 only 0.1 million cases and no deaths were reported across the country. Epidemiological surveillance was initiated in 1961, and by 1966, malaria was practically eradicated (fulfilled technical criteria) from nearly half of the country. These areas entered into the maintenance phase of the programme, which meant vertical programmatic structures were withdrawn, and malaria eradication programme was integrated into the general public health services.

However, unfortunately, a rapid resurgence in malaria incidence leading to extensive malaria outbreaks across the country in areas that had moved into consolidation and maintenance phase forced a programme reversion back into attack phase. In 1976, cases had peaked at 6.47 million which led to 59 reported deaths. Technical, administrative and operational problems of the existing anti-malaria strategy prevalent during that period led the Government of India to adopt the Modified Plan of Operation (MPO) in 1977 to reduce morbidity and prevent deaths, and the strategy changed from eradication to containment. Containment was strategized through a seven-pronged approach: Selective IRS and focal spray, active and passive surveillance, re-organization of malaria units at state, zonal, district and block level, making malaria laboratories functional at block PHC level, ensuring availability of anti-malaria drugs through DDC (Drug Distribution Centres) / FTDs (Fever Treatment Depots) in each village, initiating operational research and training, and public co-operation through voluntary agencies. An increasing Pf rate led to the rollout of the Plasmodium falciparum containment programme (PfCP) in 55 districts in 1977, with initiation of Pf drug resistance monitoring as well. The strategies under MPO led to a decrease in malaria cases to 2.18 million in 1984 and PfCP led to a decrease in Pf cases from 0.85 million in 1976 to 0.65 million in 1984.

With reduction in cases, there was a reduction in resources, and programme interventions like IRS were reduced in scope[12]. This resulted in large scale outbreaks of malaria which occurred in several parts of the country in 1994. This led to the launch of Malaria Action Programme in 1995 with focussed approaches and prioritised inputs to high endemic areas. In 1997, Enhanced Malaria Control Project (EMCP) was launched, with World Bank assistance, renewing the emphasis on malaria control in predominantly tribal areas, with additional inputs on human resources; as well as early diagnosis and prompt treatment (EDPT). Selective vector control, capacity building, behaviour change communication, operational research, Management Information System (MIS) and epidemic preparedness were the other thrust areas of this initiative. In 1998, since the focus of the programme had moved from eradication to control, the name was changed to the National Anti-Malaria Programme (NAMP). In 2003, with integration of various vector borne disease control programmes under a single umbrella, the National Vector Borne Disease Control Programme (NVBDCP) was rolled out.

World Bank supported the Enhanced Malaria Control Project (EMCP) from 1997-2005 in 100 districts of eight high malaria incidence states, including Odisha, and from 2009-2013 in 124 high endemic districts across nine states, again including Odisha. The Intensified Malaria Control Programme (IMCP) funded by Global Fund for the Fight against HIV/AIDS, Tuberculosis and Malaria (GFATM) was operational from 2005-2010 in 106 districts of 10 states, including Odisha. The mainstay of both EMCP and IMCP inputs in the project districts were Rapid Diagnostic Tests (RDTs), Artemisinin Combination Therapy (ACT), Insecticide Treated Bed Nets (ITNs) and Health Systems Strengthening (HSS).

Various such inputs and approaches from projects were harmonized under the aegis of NVBDCP in the form of:

- Surveillance and case management, including Case detection (passive and active), Early Diagnosis and Complete Treatment, Sentinel surveillance;
- Integrated Vector Management (IVM), including Indoor Residual Spray (IRS), Insecticide Treated bed Nets (ITNs) / Long Lasting Insecticide treated Nets (LLINs), Anti-larval measures including source reduction;
- Epidemic preparedness and early response; and
- Supportive Interventions, which include Capacity building, Behaviour Change Communication (BCC), Inter-sectoral collaboration, Monitoring and Evaluation (M & E), Operational research and applied field research.

Over the years, Odisha has also continued its combat against malaria through several malaria control activities in convergence with the national strategies as mentioned above and often through externally funded projects bilaterally supporting the state malaria initiatives, which included the DFID funded Odisha Health Sector and Nutrition Support Plan. The OHSNP has contributed to the programme through technical and financial support from 2007-08 onwards, primarily to support capacity building of ASHAs, monitoring and evaluation through Lot Quality Assurance Sampling (LQAS), procurement systems strengthening, LLIN procurement, distribution and behaviour change campaigns, IRS and gap funding for RDTs, ACT and synthetic pyrethroids. Innovations like the Mo Mashari initiative of providing LLINs to pregnant women in the absence of chemoprophylaxis; and to tribal residential school children in high endemic areas were rolled out.

PURPOSE AND OBJECTIVE

As mentioned earlier, the malaria situation in India has witnessed a considerable decline over the years in spite of various pitfalls in the anti-malaria activities mounted by the public health system of the country; clearly the strengths of the programmes outweighing their weaknesses. This has also been witnessed in Odisha, the malaria epidemiology of which has not been extensively studied. Hence the study of malaria epidemiology in the state, mainly focusing on temporal and spatial distribution will help in characterization of the disease trends in Odisha. This will indicate the effectiveness of the historical and current measures and hence will influence future policy with regards to the magnitude of intensification and targeting of the control measures required to achieve the ultimate goal of eliminating malaria as per NVBDCP strategies.

Consequently, this study aims to analyse the programmatic malaria data generated by NVBDCP in the state over the last eleven years, from 2003 to 2013, in order to describe the trends of the disease in Odisha and to predict the disease trends in near future in the state.

METHODS

Data

Data was collected from NVBDCP of Odisha. District-wise monthly data from NVBDCP consisted of blood samples examined from suspected malaria cases (examined by smear microscopy up to 2010 and both smear microscopy and Rapid Diagnostic Test (RDT) in post-2010 period); cases of malaria confirmed either by smear microscopy or RDT, and the number of deaths ascribed to malaria. The district-wise and month-wise data were collected and then compiled to construct the data for the state.

Data obtained from 2003 through 2013 were in a standardized, retrievable and comparable month-wise and district-wise format, hence information before 2003 was not considered for the analysis.

The month-wise data over the 11 years considered for the study were initially structured as a multiple time-series for malaria incidence/1000/year (referred to as Annual Parasite Index [API] and blood examination rate/100/year (referred to as Annual Blood Examination Rate [ABER] in malaria control parlance in India). The blood examination rate in our analysis included both samples for blood smear examination and blood samples examined by RDT in the post-2010 period. The monthly rates were annualized for convenience of spatial comparison and standardised comparison with key benchmarks of NVBDCP.

Mid-year population was used for computing these rates from 2003 to 2010, calculated based on the 2001 census population of the state and then factoring in the annual growth rate estimated for the population of Odisha. For 2011 to 2013, similar procedures were followed with 2011 census population.

DATA ANALYSIS

Estimation of trend and seasonality

Pooled analysis of Odisha data

The pooled malaria incidence data of the state from 2003 to 2013 was initially decomposed to describe the deterministic components of the malaria incidence time-series, comprising the seasonality of the disease occurrence and the secular trend. The trend was described using a locally weighted scatterplot smoothing line (lowess). The stochastic component of the time-series i.e. the seasonality-adjusted and the trend-adjusted random fluctuations were also extracted from the decomposed data. The same decomposition procedure was also repeated for blood examination time-series for the state ranging from 2003-2013.

The annual trend of malaria incidence as well as blood examination was estimated initially by modelling malaria incidence using generalized least square regression and time as the only explanatory variable in the model. A correlogram and a partial correlogram of the residuals of the initial model were graphically plotted with each time point as the lag. From the correlograms the underlying structure of the serial dependence of the residuals of the initial model was examined with regards to their order of Autoregression (AR) and Moving Averages (MA) parameters. These parameters were then included in the model, to control for the serial dependence of the residuals.

As the malaria case detection rate is used as the proxy variable for the malaria incidence in the analysis, it is expected that the rate would be subject to influences from the operational fluctuations of NVBDCP. Blood examination rate is considered as the key surveillance indicator of the programme which was the used in the multi-variable regression model to adjust for such programmatic fluctuations; an adjusted time trend of malaria incidence was computed.

Analysis of two periods of data

A major change of strategy of malaria control through NVBDCP in the state in 2009 onwards was introduced in the form of RDTs and ACT and also involvement of ASHAs for malaria surveillance, diagnosis and treatment. Hence, the historic data of 2003-2013 were also divided into two segments for our analysis: the first phase comprising 2003-2008 and the second phase comprising 2009-2013 data. Trends of malaria incidence and blood examination were examined and estimated using the same processes as above.

Analysis of districts stratified by baseline disease burden

Districts were stratified as per their Annual Malaria Incidence (AMI) of 2003, the year which is considered as the baseline for the study. The Annual Malaria Incidence of 2003 for those districts which had Annual Blood Examination Rate (ABER) of less than 10% of the population was corrected for low ABER as per NVBDCP guidelines. The districts were stratified into the four following clusters: 0-1.9, 2-4.9, 5-9.9 and $\geq$ 10, the numbers denoting the Annual Malaria Incidence of the districts for 2003. The respective clusters were named as “Low”, “Moderate”, “High” and “Very High”. There were 18 districts in the Very High, 4 districts in High, 3 districts in Moderate and 5 districts in Low clusters. The names of the districts are mentioned in the Appendix II. These districts were also high malaria burden districts of the state, which received targeted interventions[2]. Trends of malaria incidence in these four clusters were estimated using the same process as mentioned above.

Prediction

The prediction of the malaria incidence in Odisha state using the NVBDCP data from 2001-2013 was carried out using Holt-Winters exponential smoothing models. The forecasting was done for the next three years i.e. from 2014 to 2016 to have reasonable margin of errors from the existing historic data that were analyzed. The appropriateness of the predictive model was checked using Box-Ljung test.

Spatial distribution of malaria

The districts of Odisha were stratified into four groups using the above-mentioned cut-points and the districts were colour coded in the state-map using their ABER-corrected API. The exercise was conducted once at baseline i.e. 2003 and then repeated for 2008 and 2013 to display the progress of each individual district with regards to the burden of their disease.

RESULTS

The AMI of Odisha has declined to 5.28 in 2013 from 10.82 per thousand population in 2003. Annual blood examination rate of the whole state has almost remained unchanged to 11.77% in 2013 from 11.25% in 2003 (Table 1).

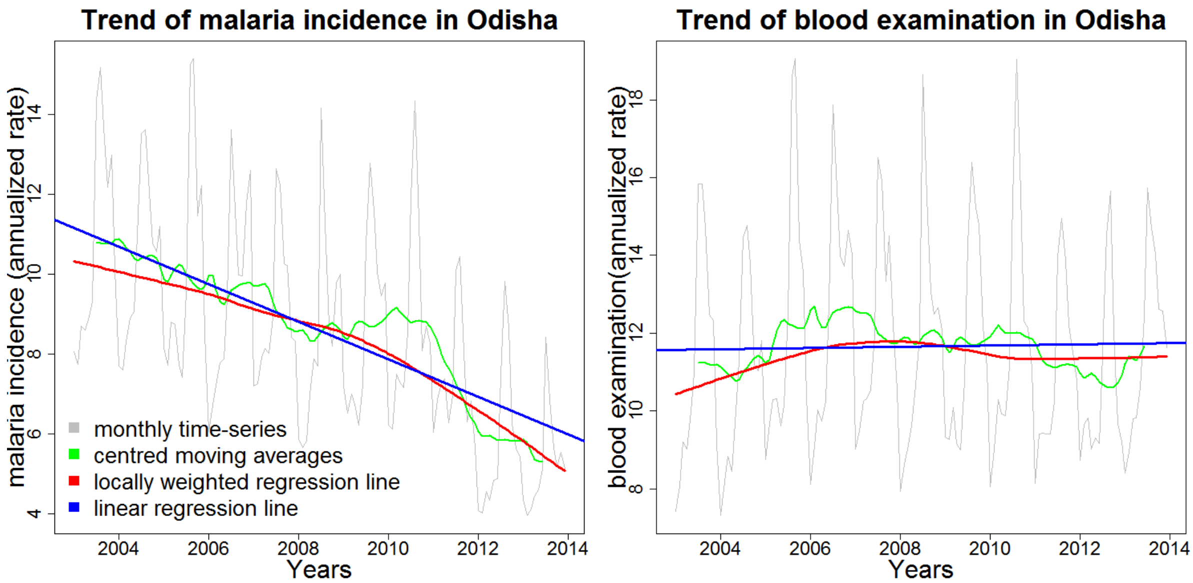
Table 1. Annual Malaria Incidence and Blood Examination Rate, 2003-2013, Odisha

Year	Malaria cases detected by NVBDCP	Blood slides examined by NVBDCP	Mid-year Population	Annual Malaria Incidence per 1000 population	Annual Blood Examination Rate (%)
2003	409445	4256451	37833200	10.82	11.25
2004	398305	4188029	38347469	10.39	10.92
2005	391830	4770794	38861739	10.08	12.28
2006	376214	4920147	39376009	9.55	12.50
2007	364318	4805306	39890279	9.13	12.05
2008	343778	4790798	40404549	8.51	11.86
2009	359493	4826635	40918818	8.79	11.80
2010	364432	4971009	41433088	8.80	12.00
2011	308374	4659729	41947358	7.35	11.11
2012	248948	4555739	42633052	5.84	10.69
2013	227990	5078508	43147321	5.28	11.77

Trends of pooled data for Odisha, 2003-2013

The pooled malaria incidence of Odisha state for the period 2003 to 2013 along with blood examination rate for the same period in the state is plotted in Fig. 1.

Figure 1. Malaria incidence vs blood examination rate, Odisha, 2003-2013



The plots demonstrate that there have been a significant peak in malaria incidence during later part of 2010.

The linear trend for malaria incidence over the 2003 to 2013 period is -0.49 per 1000 population (95% CI: -0.60 to -0.37) illustrating a significant annual decline which even got heightened to -0.54 (95% CI: -0.78 to -0.30) after adjustment for blood examination rate (Table 1). In comparison the blood examination rate underwent hardly any change with the annual decline estimated to be of 0.02 percentage points (95% CI: -0.12 to 0.08) over the same period in the state.

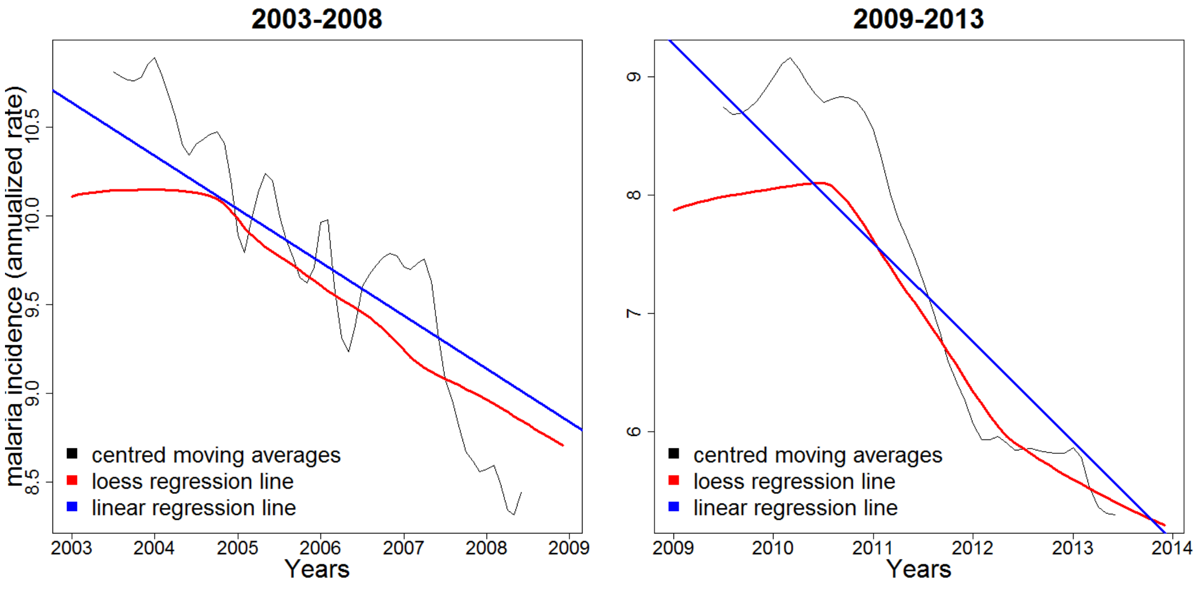
Seasonal variability of the trends

The seasonal variability for malaria incidence was noticeable with a near monotonous pattern over the years, with mean highest monthly incidence registered during July, showing a 41% increase of incidence from the annual mean incidence. The lowest incidence was observed on an average in the month of January when 25% less cases were emerging than the annual mean incidence (graphs shown in Appendix I). Over the period the peak incidence of the disease showed a slight shift to the right, July being the month of average peak incidence in 2003-2008 period which changed to August during 2009 to 2013.

Analysis of two periods

The linear slope of decline in malaria incidence between 2003 and 2008 was flatter as compared to the period of 2009 to 2013 (Fig. 2) in spite of a clearly discernible peak in incidence in 2010 followed by sharp decline thereafter. The slight slowing of the decline from 2012 onwards is also evident from the non-linear smoothers in Fig. 2.

Figure 2 Malaria Incidence during two periods, Odisha, 2003-2008 vs 2009-2013



The estimates of the annual decline for 2003-2008 was -0.44 per 1000 population (95% CI: -0.63 to -0.26) which after adjustment for blood examination rate increased to -0.57 per 1000 population (95% CI: -0.77 to -0.37). In comparison, the annual decline during the period of 2009-2013 was -0.81 (-1.46 to – 0.18) which slightly increased to -0.83 (-1.30 to -0.37) after adjustment for blood slide examination(Table 1).

The blood slide examination rate increased by 0.28 percentage points (95% CI: 0.06 to 0.50, p=0.013) annually during 2003-2008 in the state whereas the change during 2009 to 2013 was not significant.

Table 2. Trends for Malaria Incidence per Annum

	Trend estimate* of malaria incidence – unadjusted	Trend estimate* of malaria incidence – adjusted for blood examination rate
Pooled Odisha, 2003-2013	-0.49 (-0.60 to -0.37), p<0.0001	-0.54 (-0.78 to -0.30), p<0.0001
Two periods		
Odisha, 2003-2008	-0.44 (-0.63 to -0.26), p<0.0001	-0.57 (-0.77 to -0.37), p<0.0001
Odisha, 2009-2013	-0.81 (-1.46 to – 0.18), p=0.015	-0.83 (-1.30 to -0.37), p<0.0001
Clusters as per disease burden at baseline 2003		
Very High	-0.78 (-1.06 to -0.49) , p<0.0001	-0.69 (-0.94 to -0.33) , p<0.0001
High	-0.34 (-0.44 to -0.25) , p<0.0001	-0.44 (-0.48 to -0.40) , p<0.0001
Moderate	-0.24 (-0.29 to -0.19) , p<0.0001	-0.27 (-0.31 to -0.23) , p<0.0001
Low	-0.04 (-0.08 to -0.01), p=0.013	-0.04 (-0.08 to 0.00), p= 0.06

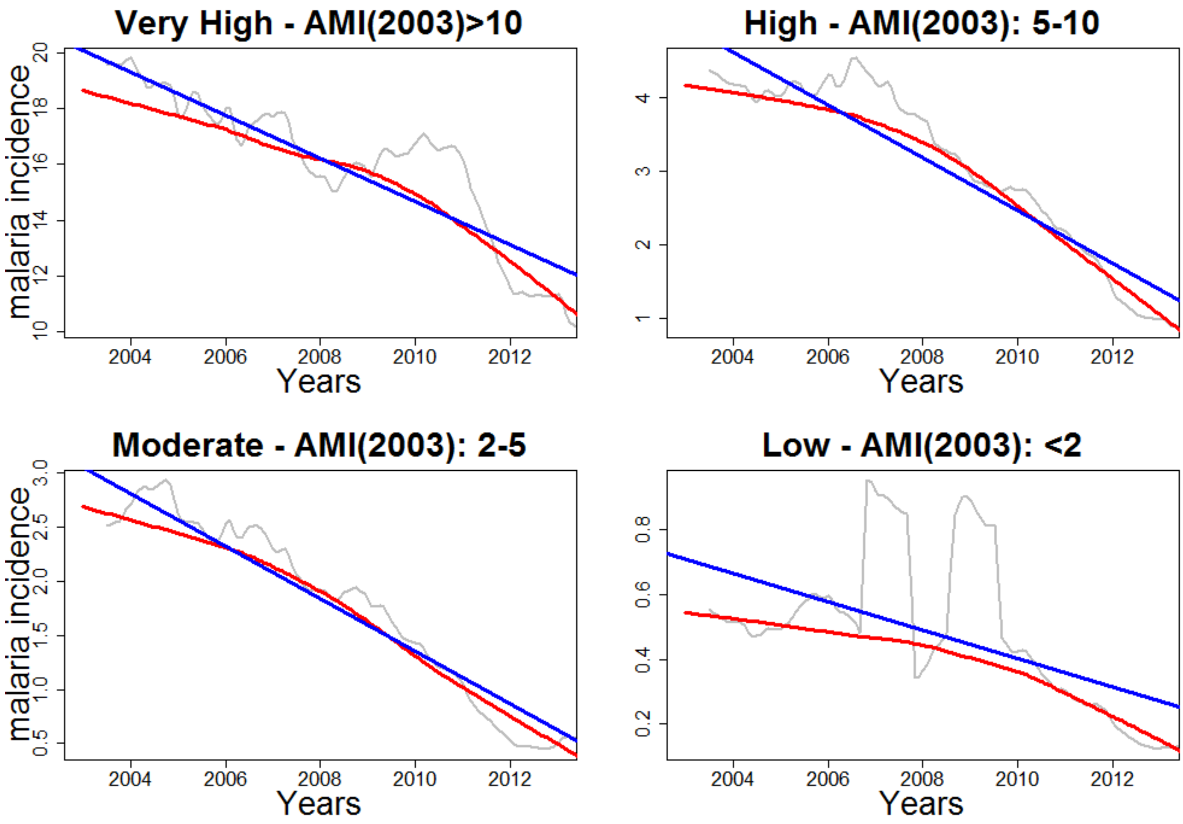
*Trend estimates are per 1000 population per year

Analysis of districts stratified by baseline disease burden

The annual relative decline of malaria incidence in Low burden districts had flatter gradient than the other three clusters of districts where the declines were comparable (Fig 3.).

The blood examination rate- adjusted gradients were -0.69 (95% CI: -0.94 to -0.33); -0.44 (-0.48 to -0.40); -0.27 (-0.31 to -0.23) and -0.04 (-0.08 to 0.00) for Very High, High, Moderate and Low clusters respectively. For the first three clusters the annual decline although varying in absolute terms were actually very similar in terms of relative decline to their baseline; the relative estimates varying between 3-6% per annum. The blood examination rate registered a decline over the years in Very High cluster, the annual percentage point decline estimated to be -0.29 (95% CI: -0.45 to -0.14). The other three clusters experienced increase in blood examination rates during these eleven years, the annual estimates of which are 0.20 (0.39 to 9.08) for High, 0.18 (95% CI: 0.05 to 0.30) for Moderate and 0.28 (95% CI: 0.24 to 0.34) for Low.

Figure 3. Trend of Malaria Incidence in Four Clusters, classified on baseline AMI (2003)

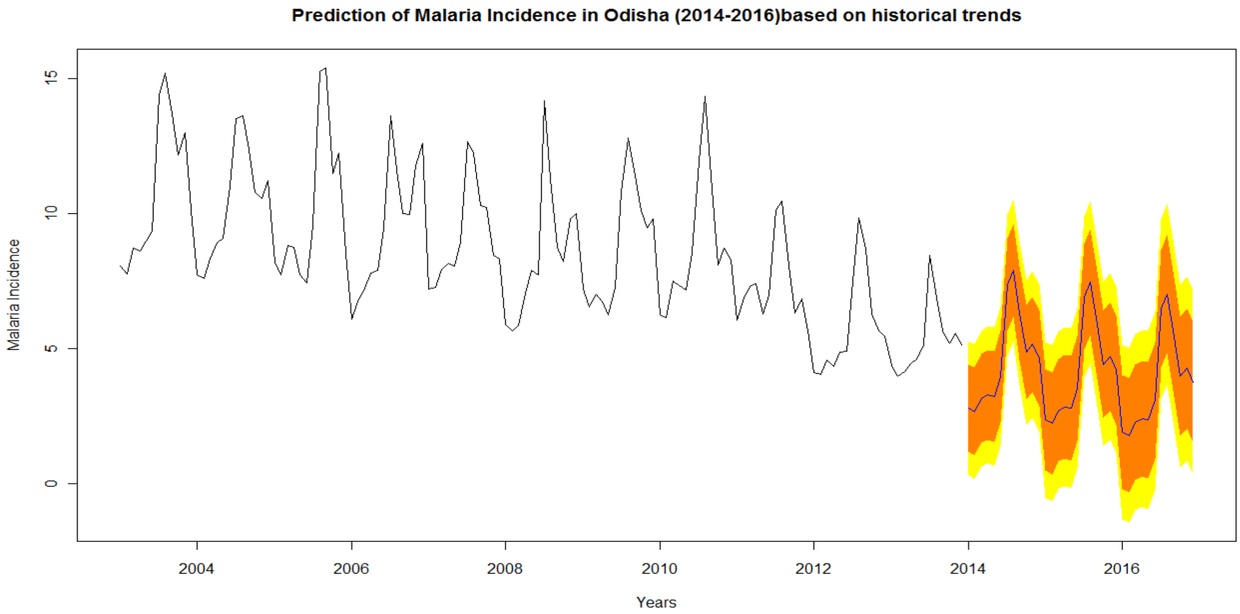


The districts in the low and moderate incidence clusters have already reached the elimination levels for malaria (AMI of 1 or less per 1000 population), and the high incidence cluster is quite likely to reach by 2017. The very high incidence cluster started out at very high levels, and has shown the steepest decline over the eleven year period, however, it is not likely to reach the elimination level by 2017 at the current rates of decline. However, for districts that have attained the elimination level, independent surveys might need to be undertaken in order to validate the findings from the reported data.

Prediction

The forecast for the next three years is described in Figure 4 which shows that the decline is likely to stagnate if the current trends continue.

Figure 4 Forecasting malaria incidence for 2014-2016 based on trends from 2003-2013

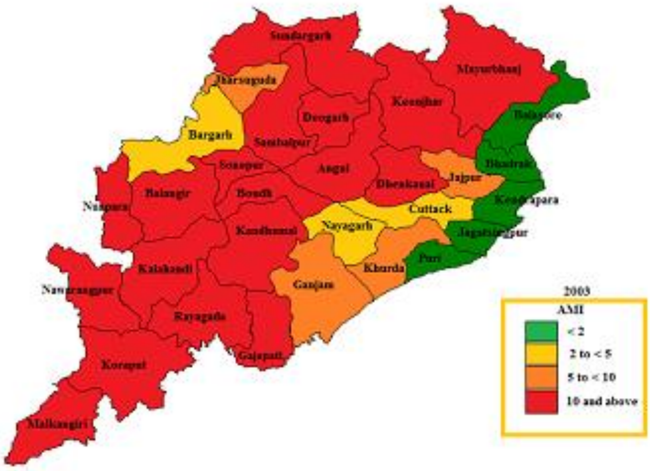


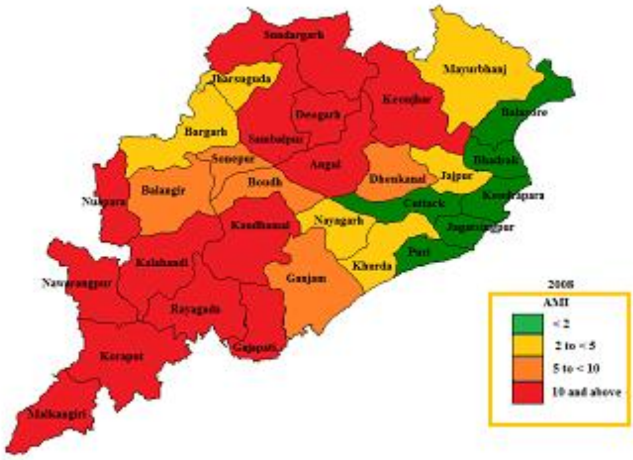
The prediction interval (yellow representing 95% and orange representing 80% margin of error) also indicate that the rapid decline that could be achieved especially during the period of 2009 to 2013 may not be sustained unless additional or sustained inputs are contemplated. This may also imply that the eliminationl level Annual Malaria Incidence of $\leq$1 per thousand per year may not be achieved by 2017 which is the current goal of NVBDCP.

Distribution of malaria

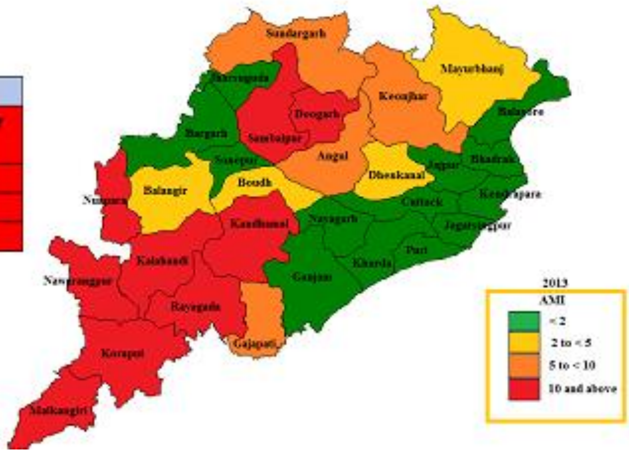
Malaria continues to ravage seven southern districts of Kandhamal, Kalahandi, Rayagada, Koraput, Nawarangpur, Nuapada and Malkangiri and two central districts of Sambalpur and Deogarh, which are consistently in the Very High incidence zone from 2003 through to 2013. Success has been achieved in northern and western districts, some of which have been shifted from Very High to other less-burden clusters. The coastal five districts remain in the Low cluster throughout the study period.

Figure 5 Status of AMI of the districts of Odisha, 2003-2013:





Year	Number of Districts			
	AMI < 2	AMI 2 to < 5	AMI 5 to < 10	AMI 10 or More
2003	5	3	4	18
2008	6	6	5	13
2013	13	4	4	9



DISCUSSION

The study examined the temporal trend of malaria in Odisha state over the previous completed eleven years (2003-2013) in the light of various prevention and control measures undertaken during this period by the National Vector-borne Disease Control Programme (NVBDCP) in the state, supported by various development partners, including DFID , World Bank and GFATM.

In eleven years, the state has achieved an average decline of approximately 5% every year from its annual malaria incidence in 2003, when it was almost 11 per thousand population in the state. This decline was achieved with a steady blood examination rate which is a key indicator of effective surveillance by the programme.

The average annual decline in malaria incidence during the period between 2009 and 2013 was steeper than that was achieved between 2003 and 2008, in spite of an increase in case detection in the early half of 2010.

This surge in malaria case detection by NVBDCP in Odisha in 2010, can be attributed to the intensification of early case detection and treatment activities which started from 2007-08[12] at community level. The sharp decline of incidence from the latter part of 2010 in the state was perhaps attributable to effective management of a large number of malaria cases leading to a contraction of the reservoir of malaria parasite in the community. This was also helped by measures to interrupt the malaria transmission cycle. The introduction and intensification of the various effective anti-malaria approaches are discussed in the following sections.

The National Malaria Drug Policy 2007 introduced ACT in view of evidence of chloroquine resistance[13], which was then gradually rolled-out in the states, including in Odisha from 2008 onwards. Implementation of RDT by NVBDCP for early detection of cases at the community level were also introduced during that period. Integrated vector control and a whole new perspective on monitoring and evaluation of the programme and behaviour change communication for malaria were also key drivers of increased surveillance, treatment seeking behaviour, improved prevention and case management measures, thereby, leading to positive outputs of the Odisha malaria programme

While the strategies mentioned above were part of the national mandate across high burden states of the country, a number of things stand out in the case of Odisha, which can perhaps explain the sustained steep fall between 2009 and 2013 (obtained through personal communication from State NVBDCP, Odisha):

- Strong governance, and an extremely supportive bureaucratic and administrative environment. Fixed day technical committee meetings were held every month under the chairpersonship of the Health Secretary, and with the presence of key Directors.[14]
- Strong political will, demonstrated by willingness of the Government of Odisha to invest extensively on LLINs, initially leveraging funds from development partners like DFID, but later on from state budget.
- A strong technical team at NVBDCP
- A coordinated technical support group, consisting of treating physicians, academia, researchers, policy analysts, development partner representatives, epidemiologists, entomologists and domain specialists on communication, partnerships and human resource management
- Multiple stakeholder involvement, including various Directorates of Health Department, Department of Women and Child Development, Panchayati Raj Institutions, Forest and Environment departments, etc.
- Effective coordination and leveraging of strengths of development partners like DFID, World Bank, GFATM, WHO, MMV, etc.
- Well planned and innovative communication strategies to create and enhance awareness and demand for services.
- Availability of DFID funded OHSNP for technical and flexible financial support to address gaps in logistics supplies.
- Good leveraging of support from World Bank and GFATM for components supported through their respective projects.
- Demonstrated ability to advocate for and sustain interventions initiated using external funding.

At the ground-level in the state the intensified activities that were taken forward across all high burden districts from that period onwards and then in other districts in a staggered fashion include training and deployment in malaria programme of the ASHA, the front-line health volunteer workforce in the state; the distribution of LLINs to the community members in the high burden districts; the deployment of newly-recruited and trained Male Health Workers for Malaria; introduction and wider coverage of RDT kits as well as ACTs; and strengthening of the malaria surveillance and information system through use of standardized formats.

To validate the information obtained through communication with NVBDCP, Odisha on successful strategies during the 2009-2013 period, we examined the Lot Quality Assurance Sampling (LQAS) survey results, technically supported by the Liverpool School of Tropical Medicine, with funding from DFID (using personal communication with the authors of the manuscript related to LQAS data, Valadez *et al.*,which has been submitted to a peer-reviewed journal for publication and is currently undergoing review). The LQAS which is an externally supported survey to evaluate programmatic interventions by NVBDCP, reported encouraging changes in various components between November 2009 (first round of LQAS) and November 2012 (6^{th} round of LQAS) in the initial set of districts, which includes increased protection of adults and children (27% and 42% increase in protection respectively) through use of LLINs, improved treatment-seeking behaviour and a surge in treatment of diagnosed cases (increase of 63%). Inclusion of ASHAs in early diagnosis and treatment and their knowledge enhancement with regards to use of RDT and ACT was also a major observation of LQAS. However LQAS also underscored weaknesses in the programme such as lack of knowledge in the community with regards to washing and drying of LLIN thus compromising their lifespan and sporadic stock-outs of RDTs in some districts. The LQAS results have been critical to the program management in taking mid course corrective actions (Valadez et al, yet to be published, reports that initial LQAS intervention districts exhibited significantly greater change in three quarters of strategies, and that LQAS results appeared to support district managers to increase coverage in under-performing areas, in the presence of diligent managers).

The absolute decline of malaria incidence was proportionately higher in the districts with higher disease burden at baseline i.e. 2003: except the decline was not significant in the cluster with districts with low endemicity as would be expected, as there was small malaria burden at baseline in those districts. The allocation of resources to the districts were contingent upon their initial malaria burden (personal communication from State NVBDCP cell), hence perhaps higher decline in high endemic clusters; though the magnitude of decline relative to their initial burden was similar in all the clusters except the cluster with low burden districts.

This perhaps indicates that over time the allocation of resources were not very uneven, and were proportionate to disease burden of the districts, though new programmatic measures were perhaps initiated in the areas where they were needed most and then scaled-up in other areas.

The sharp decline of later half of 2010 and 2011 slowed down in 2012 and 2013 which is also illustrated in the prediction for the next three years of 2014 to 2016. India historically has witnessed such slow-downs after spectacular achievements in malaria control. The conspicuous gain from its inception in 1953 up to 1966 by the National Malaria Control Programme was reversed due to complacent premature dismantling of the programmatic infrastructure and withdrawal of resources from the programme by the planners and policy-makers, which led to a huge resurgence of the malaria problem in the country within a decade[14,15].

To avoid any recurrence of such inappropriate resource-withdrawal and shifting of the “spotlight” from the malaria problem in the state, intensified activities that yielded results have to be sustained. The goal of achieving annual malaria incidence of <1/1000 seems unlikely for the whole state from the prediction model; moreover the southern 7 states that include Kandhamal, Kalahandi, Raygada, Koraput, Nawarangpur, Nuapada and Malkangiri continue to be in the Very High (>10 Annual Malaria Incidence) zone of endemicity for the disease consistently over the last eleven years though each of these districts achieved remarkable decline from higher baseline burden in the nineties. Targeted allocation of resources for high burden districts or blocks may be a strategy for future, more so to offset any trend of slackening of surveillance in those areas as was evident by the decline of blood examination rate in Very High cluster of districts. On the other hand this decline in blood examination rate in Very High cluster perhaps can be innocuously attributed to decrease in fever cases in those communities with sharp decline of malaria.

Substantial regional differences in the malaria burden is expected given the variability of topography, climate, socio-economic condition and ethnology of the state and so is the variability in response of various districts to programmatic measures is not uncommon. Focus should not be diluted in targeting “high risk” zones and every effort should be made to bring them up to the level of districts with lower burdens so that globally the state of Odisha can achieve the goal of elimination of the disease and consolidate such success forever.

Limitations

The main limitation of the study is that the data is acquired from the monthly programmatic reports of NVBDCP. Hence, the malaria incidence that is being analysed in the study is actually the cases detected and reported by the programme; and this is definitely not a true reflection of all the incident malaria cases in the community. Studies have shown that there may be a substantial underestimation of mortality due to malaria in the country by NVBDCP as well as World Health Organization, which may be due to under-detection of cases by the programme and its failure to ascribe the cause of many undiagnosed febrile deaths to malaria. This may also suggest that many malaria cases are also not being detected and treated by NVBDCP, as those "left-outs" may be seeking care from other sources such as private medical system or non-formal medical practitioners. Hence the malaria incidence that we have analysed is an underestimation of the true incidence in the state, but it can nevertheless be argued that such underestimation is unlikely to influence our trend estimates substantively which have shown a significant decline of the disease based on NVBDCP data. This is because the portion of the "uncovered" population is unlikely to have increased with time; hence the lack of coverage is not spuriously driving the decline, one may argue. That pool of "uncovered" malaria cases is rather expected to have diminished over time as many control measures were being intensified to increase access to NVBDCP in the state, which was also reflected through the maintenance of a steady blood examination rate by the programme over this eleven year period in the face of declining disease trends.

Although using secondary programmatic data, the strength of this study is that the decline of malaria incidence that was demonstrated over the time was unlikely to be due to the worsening of programme surveillance performance only, because the trend of malaria was adjusted for a key operational variable which is blood examination rate. The adjusted trend estimates have factored in any major changes in the programme performance over the study period and have computed trends independent of surveillance performance.

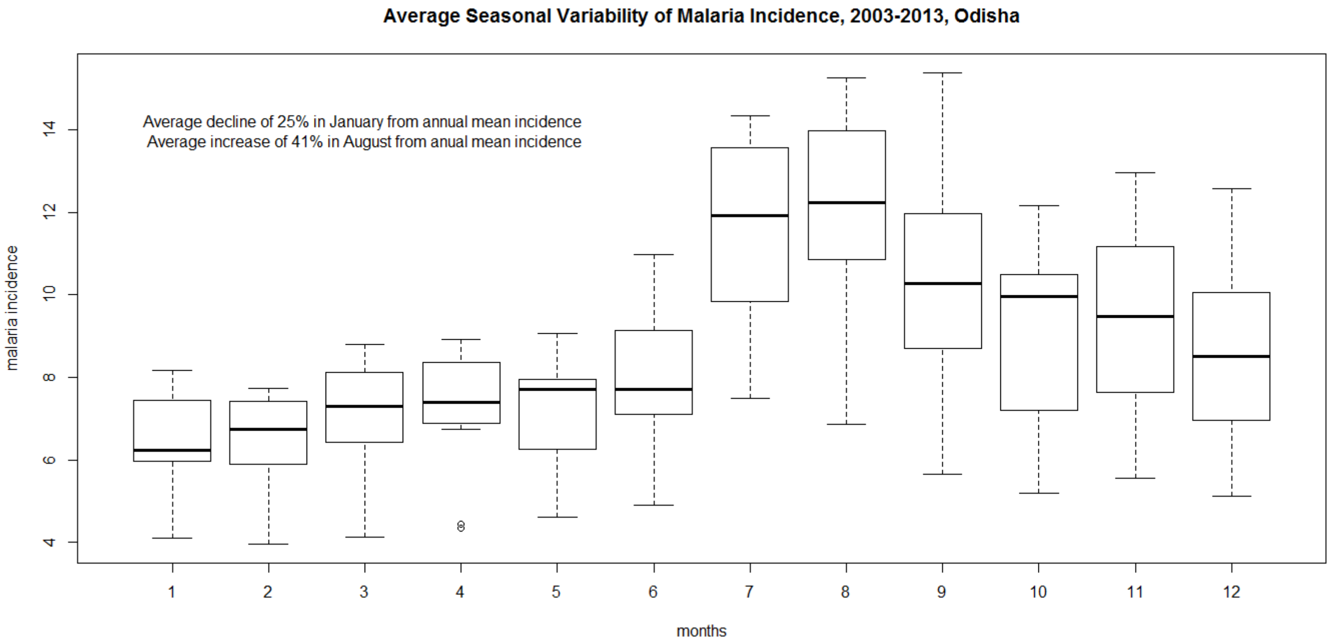
ABER, the indicator for programme surveillance, included results from both smear microscopy and RDTs from 2010 onwards, and before that, from smear microscopy only. Under ideal circumstances, blood examination by adequately trained personnel should have less error attached than through RDKs due to test sensitivity and specificity – which may also be affected by poor storage/out of date/high temp exposure/mis-reading. In spite of over 100 published RDT trial reports, comparative assessment is difficult because (1) trials do not share common guidelines; (2) clinical and epidemiologic characteristics of the study populations, especially the parasitemia level vary; (3) reference standards are different; even among those using Giemsa microscopy, reading rules and microscopist skills vary; and (4) products of different lots may differ in quality or be damaged by extreme temperature or humidity during transportation and storage[16] (http://www.wpro.who.int/sites/rdt/reviews_trials/).

Another limitation of the study is the irretrievability of data with regards to incident malaria cases among children and adolescents before 2011. Hence trends of malaria among children and adolescents could not be computed for the whole study period. As a post-hoc analysis the month-wise and state data for three years (2011-2013) of young population suffering from malaria were analysed. The percentages of cases in 0-4 and 5-14 years age-group were 11% and 27% of all cases respectively in 2011 compared to 13% and 32% in 2013. The annual trend was not statistically significant, though a declining trend was evident in these age-groups.As the time-points for month-wise time-series data analysis for children and adolescents over these three years were only 36, this underpowered this analysis pf paediatric cases considerably. But perhaps it can be concluded that the decline experienced by overall malaria incidence in the state also played out in this younger age-group as their proportional contribution to the overall cases between 2011 and 2013 did not change substantially.

Conclusion

To conclude, our study has shown that there is a substantial decline in malaria incidence over the years 2003 - 2013 likely due to intensified programme interventions by state NVBDCP and support provided by various development partners. The rate of decline is very sharp from 2009 to 2013, which correlates with the bulk of interventional inputs. However, many districts still continue to have very high burden of malaria in the state and hence a stagnation of the success or resurgence of the problem in those areas as well as in neighbouring regions cannot be ruled out if activities and control measures that achieved the success are not sustained in future. In addition, data for the entire state indicates that trends seem to be slowing down from 2012, highlighting the need to sustain interventions in a sustained manner, with focus on additional human resources, uninterrupted supply of adequate drugs and diagnostic tools, integrated vector control management by LLIN and IRS, and continuous capacity building, inter-sectoral convergence and community mobilisation and behaviour change processes. Adequate resources need to be available to the State NVBDCP program to sustain the pace of activities that was initiated from 2008 onwards, in order that the state reach elimination targets of less than one case per thousand population.

Appendix I



Average Seasonal Variability of Malaria Incidence, 2003-2013, Odisha
Average decline of 25% in January from annual mean incidence
Average increase of 41% in August from anual mean incidence
malaria incidence
4
6
8
10
12
14
1
2
3
4
5
6
7
8
9
10
11
12
months

Appendix-II

Status of AMI in Odisha in 2003 (Baseline year)

	Name of the Districts with AMI < 2 (LOW)
1	Balasore
2	Bhadrak
3	Kendrapara
4	Jagatsingpur
5	Puri
	Name of the Districts with AMI 2 to < 5 (MODERATE)
6	Cuttack
7	Nayagarh
8	Baragarh
	Name of the Districts with AMI 5 to < 10 (HIGH)
9	Jajpur
10	Khurda
11	Ganjam
12	Jharsuguda
	Name of the Districts with AMI 5 10 or more (VERY HIGH)
13	Mayurbhanj
14	Keonjhar
15	Dhenkanal
16	Angul
17	Deogarh
18	Sundargarh
19	Sambalpur
20	Sonepur
21	Boudh
22	Kandhamal
23	Bolangir
24	Kalahandi
25	Rayagada
26	Koraput
27	Gajapati
28	Nuapada
29	Nawarangpur
30	Malkangiri

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