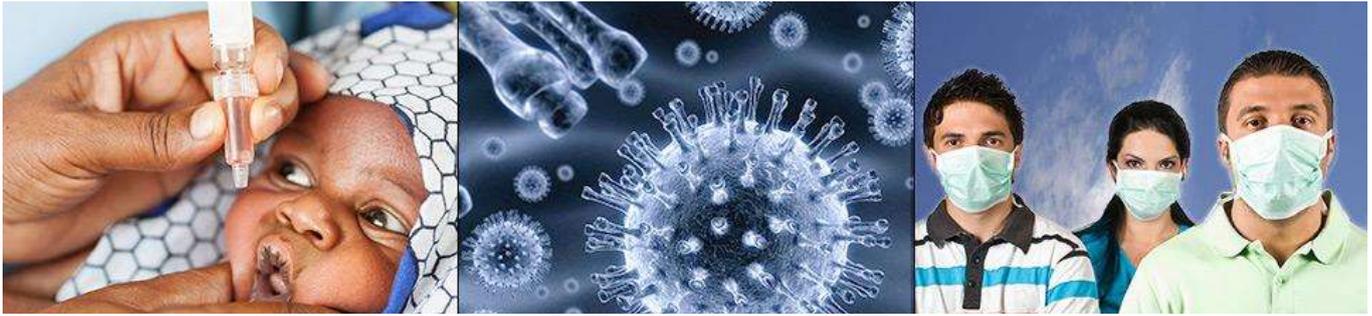


WEATHER ELEMENTS IMPACTS ON MALARIA SURVEILLANCE IN THE COASTAL BLOCKS OF RAMANATHAPURAM DISTRICT, TAMILNADU, INDIA.



Original Research Article

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ABSTRACT

Mosquito-borne diseases particularly malaria is becoming most dreaded health problems in the Coastal Blocks of Ramanathapuram District, Tamilnadu, India. In Coastal Blocks of Ramanathapuram District, malaria is seasonal and unstable, causing frequent epidemics. For transmission of malaria parasite, climatic factors are important determinants such as rain fall, temperature relative humidity and wind that can negate climatic influences. It is aimed to find out the effect of climatic factors such as temperature, rainfall, relative humidity and wind on malaria incidence with particular emphasis to capture the essential events. Cartographic technique and simple correlation analysis were carried out by using Geographical Information System (GIS) and SPSS.

A set of transmission windows typical to India have been developed, in terms of different temperature ranges for a particular range of relative humidity, by analysing the present climate trends and corresponding malaria incidences. El Nino years were used to find out the relationship between the climatic variables and the incidence of malaria. Occurrence of El Nino may be a alarm for taking precautions. The climatic variables such as temperature, rain fall, humidity and wind speed correlate with incidence of malaria in the Coastal Blocks of Ramanathapuram District.

Climatic factors such as temperature, rainfall, relative humidity and wind are playing major role on outbreak of malaria especially in the costal block of Ramanathapuram district of Tamil Nadu. More rainfall and El Nino years are becoming a alarm for precautions practice for the administrators. So this research may help administrators to take necessary action to control the malaria incidence.

Keywords:

Climate determinants,
 Malaria incidence,
 Mosquito borne disease,
 Transmission window,
 Vector and El Nino.

I. INTRODUCTION

Malaria is a major endemic disease which is still a challenge to the Indian health system. In India nearly 1.6 million malaria cases and around 1000 deaths were reported in 2010. Epidemiologically, malaria is extremely complex; it is a focal disease the distribution of which is influenced by a multitude of factors related to human, mosquito and parasite population, as well as to the environment. Environmental conditions play an important role in the transmission dynamics of malaria, as the parasite has to pass its developmental cycle in the mosquito. The emergence, transmission and sustainability of malaria depend largely upon the local factors. Control strategies, therefore, cannot be generalized and applied to any area. For effective control programme, regional variation and characteristics have to be appropriately included. The best way of tackling this disease is to frame a broad national action plan with provisions for regional modifications. For this, it is necessary to conduct a number of regional analysis. The present investigation is one such attempt to study the malarial incidence in an endemic region of Tamilnadu.

Location, Extent and Administrative Units

Ramanathapuram district is one of the coastal districts located in the southeast corner of Tamilnadu and has an area of 4089 sq. km. For administrative purposes Ramanathapuram District is divided in to 2 Revenue Divisions (Ramanathapuram and Paramakudi), 7 taluks namely Ramanathapuram, Tiruvadana, Paramakudi, Kadaladi, Kamuthi, Muthukulathur and Rameswaram. These taluks are further sub divided into blocks. The district as a whole has 11 blocks. However, since the present study has taken Malaria, which is more prevalent in wet condition, only coastal blocks are considered. There are six coastal blocks namely Thiruvadana and R.S. Mangalam (Thiruvadana taluk), Ramanathapuram, Thirupulani and Mandapam (Ramanathapuram taluk) and Kadaldi (Kadaladi taluk). All these 6 blocks are in the main land. In addition Rameswaram which is an island and part of Mandapam block connected with mainland by road and Pamban Railway Bridge is also considered in the present study due to its coastal location (Fig.1). The coastal blocks extend over an area of 2401 sq.km.

The study area of coastal blocks lies between 9° 09' and 9° 98' North latitudes and 78° 23' and 79° 45' East longitudes surrounded by Pudukkottai district in the north, Sivagangai district and Paramakudi, Muthukulathur and Kamuthi Taluk of Ramanathapuram district in the west and by Tuticorin district in the south. The eastern side of the district is bounded by the Palk Strait and Gulf of Mannar. The unique feature of the District is the longest coastline measuring about 271 km accounting for nearly 1/4th of the total length of the coastline and very high marine fish production of the State. In these coastal blocks, general elevation varies from 2m found in the Rameswaram Island to 35m above the mean sea level in the western boundary region of Tiruvadana block (Fig. 1). The slope of the land decreases from west to east towards the coast. The coastal region of Mandapam and Kadaladi blocks consist of sand dune looking like small hillocks.



Fig.1

1.2 Aims and Objectives

The purposes of this research were to describe the epidemiology of malaria in Coastal blocks of Ramanathapuram district a 10-year span; to retrospectively analyze climatic factors of malaria at local scales; to increase knowledge of malaria transmission patterns; and to aid in area-specific malaria control efforts. The objectives of this research were:

- To assess the seasonal distribution of malaria incidence by region in the selected two time points of 2001 and 2010;
- To assess the spatial pattern of malaria incidence using Geographic Information System (GIS) technologies, from 2001 to 2010 in the coastal blocks of Ramanathapuram district;

II. METHODOLOGY

Source of Information and Database

For the present study secondary data have been collected. Secondary data of disease surveillance data PHC wise between the study periods of 2001 - 2010 have been collected from the annual report of NVBDCP in Ramanathapuram DPH. From the report required data have taped PHC wise as total number of positives and seasonal pattern. API is calculated and represented spatially. The climatic data were collected from IMD, Pune for last 40 years. The study area details are collected from the District Statistical Department.

Techniques used in the Present Study

The present study used the simple Cartographic and statistical techniques. The generated data is tabulated and analyzed. The results are represented through suitable cartographic techniques. SPSS 19 was used for extracting principle components to bring out the controlling factors. Thematic mapping layers for results are generated using ARCGIS 9.3 environment.

Study Background

In 2011 the total rural malaria cases in Tamilnadu was 6602. Out of this 60% of the cases occurred in Ramanathapuram District alone. Thus it is validated that Ramanathapuram District is the most endemic district in Tamilnadu as far as malaria is concerned.

Within Ramanathapuram District, the spatial distribution of malaria cases is concentrated only in a few blocks. Altogether Ramanathapuram District has 11 blocks. Of these there are 6 blocks along the coast and 5 in the inland area. A perusal of registered malaria cases indicates that coastal blocks have more than 90% of the cases in the District (Table 1).

Table 1
Incidence of Malaria – Ramanathapuram District and Coastal Blocks

Sl.No	Years	District Total Cases	Coastal Blocks Total Cases	% Share of Coastal Blocks
1	2001	880	809	91.9
2	2002	1066	938	88.0
3	2003	6264	6131	97.9
4	2004	4778	4500	94.2
5	2005	6710	6591	98.2
6	2006	2874	2827	98.4
7	2007	3588	3497	97.5
8	2008	2841	2797	98.5
9	2009	1828	1819	99.5
10	2010	3253	3237	99.5

Compiled by the Investigator

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Even among the six coastal blocks, incidence of malaria is more along the Gulf of Mannar coast compared to northern coastal blocks. R.S Mangalam and Tiruvadana blocks are comparatively less endemic to malaria than the other coastal blocks. Because of this pattern, the present investigation has specifically earmarked the six coastal blocks of Ramanathapuram District as the study area.

For an effective health care planning, the delivery system should be well structured. Since the incidence of malaria is mostly found in rural Ramanathapuram District, the effective mechanism to control the disease could be channelized only through the Primary Health Centre. Hence for the present investigation, the six coastal blocks together form the macro unit while the service areas of Primary Health Centres form the micro unit.



Fig.2

There are 34 PHCs in the coastal blocks of Ramanathapuram District in 2011. However, in 2001 there were only 30 Primary Health Centres. In 2008, two new PHCs were established at Appanur and Melasirupothu and they are carved out of the erstwhile Sayalkudi PHC. Similarly Regunathapuram PHC was newly created from Periyapattinam PHC due to its high endemic nature. Yet another new PHC was created in Tiruvetriyur from Tondi and Pandukudi PHCs. Thus at present, there are 34 PHCs in the study area (Fig. 2). Each PHC may have a few Health Sub Centres (HSC) for effective dissemination of health care delivery. For all subsequent maps name of PHC were not given since they are all drawn taking Fig. 2 as base. Having discussed the basic details regarding incidence of malaria, it is apt to explain the Seasonal pattern at this juncture.

Seasonal Dynamics of Malaria Cases-2001

India Meteorological Department (IMD) designates four official seasons namely, Winter, Pre-Monsoon, Monsoon or Rainy Season and Post-Monsoon for India as a whole. Almost all climatic parameters like temperature and rainfall are analyzed based only on these seasons.

Winter season normally covers January and February while Pre-monsoon season extends from March to May. Monsoon season normally occurs between June and September. October to December is considered as Post-monsoon period. Sometime this is also referred to as Retreating or Northeast monsoon period. As far as Tamilnadu is concerned, this Northeast monsoon brings more rain than the Monsoon season, particularly for the coastal region. For the present analysis also the same four seasons are considered.

In 2001, maximum number of malaria cases (60%) occurred in the Monsoon season followed by Post-monsoon season (22%). Winter (5%) had the minimum incidence of malaria.

During the Winter season of 2001, only one-fourth of the total PHCs had incidence of malaria. The maximum of 21 cases is found in Pamban PHC (Table 4.8). Mandapam

and Pudumadam PHCs of Mandapam Block had six malaria cases each. Thondi in Tiruvadana block, Valanur in Tirupullani block and Ramanathapuram urban PHCs have 3 malaria cases each, while Mangalakudi and Erwadi PHCs have two and one respectively. It may be observed that the distribution during winter shows scattered pattern (Fig. 3.1). During the Pre-monsoon period almost 50 % of PHCs have no malaria cases. In another 50% of the PHCs, Thangachimadam (32), Pamban (24), Pudumadam (13) and Mandapam (12) PHCs have more incidence of malaria (Table 4.8). Ramanathapuram, Erwadi and Tirupullani PHCs have 4 cases each whereas Thondi, Valanur and Valinokkam PHCs have two cases each. Another six PHCs have only one malaria case each.

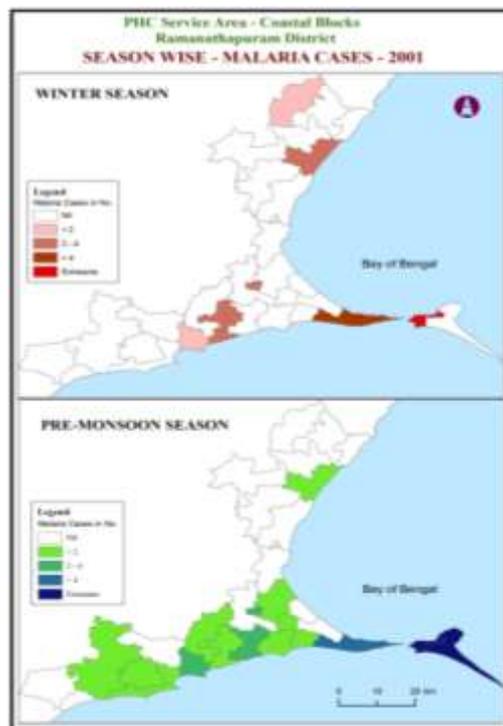


Fig 3.1

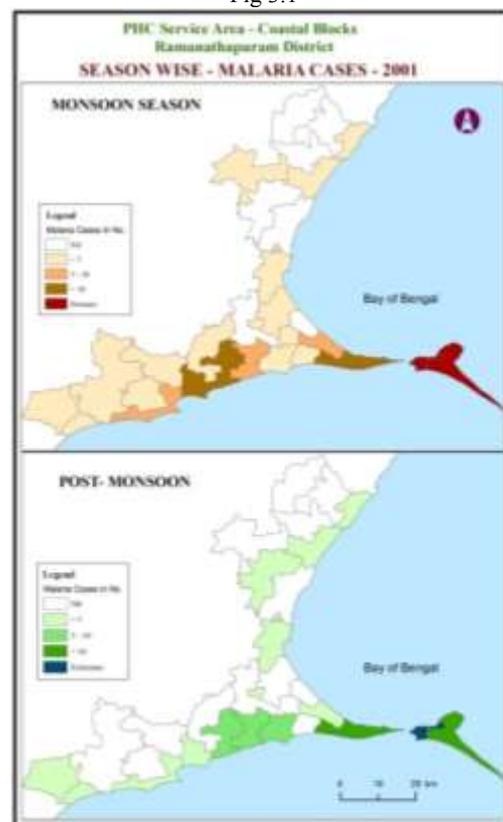


Fig 3.2

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Monsoon period does not give maximum rainfall to the study area. Only 11% of annual rain occurs during this season. In spite of it, the maximum number of malaria cases in 2001 occurred during this season. Among the 30 PHCs no malaria incidence was recorded in seven PHCs. On the other hand extreme concentration of malaria was reported in Pamban (214) and Thangachimadam (93) which together account for two-thirds of the total malaria cases. Mandapam (47), Valanur (33) and Pudumadam also reported sizable number of malaria cases (Table 4.8). Among the six coastal blocks, Kadaladi and Mandapam seem to be more endemic in 2001 during this season (Fig. 3.2).

For the study area, Post-monsoon is a period of maximum rainfall. Since number of rainy days is more and winds are stronger, stagnant water for breeding of mosquitoes is disturbed more. This may be a reason for comparatively lower incidence (22%) of malaria in this season. The extreme level of 68 cases was reported in Pamban PHC (Table 4.8). Thangachimadam (30), Mandapam (22) and Pudumadam (16) PHCs also reported significant number of malaria cases in 2001 (Fig. 3.2). Tirupullani PHC has 8 cases while Valanur and Periyapattinam PHCs have 7 cases each. There are 13 PHCs where no malaria was reported.

The varied dimensions of spatial and seasonal pattern of malaria in the study area have been elaborately discussed so far. Control measures for treatment of malaria varies depending upon the demographic parameters, particularly age structure. Hence an analysis of gender and age group of malaria patients will throw vital information on the nature of disease and vulnerability of the population in an area. Hence it is attempted here.

Seasonal Dynamics of Malaria Cases - 2010

The seasonal pattern of malaria in 2010 also shows that the higher incidence of malaria occurs during the Monsoon season and lower incidence during Winter. However, share of monsoon season declined from 2001 (60%) to 2010 (44.5%). Table.2 show the seasonal distribution of malaria cases in the study area. It may be noted that except 2003 and 2004, the highest share of malaria cases occurred only in Monsoon season. In 2003, Pre-monsoon recorded higher incidence. In 2004 Post-monsoon or northeast monsoon recorded a higher incidence. In 2010 nearly one-third of the malaria cases were reported during the Northeast monsoon period.

Only 13 PHCs have incidence of malaria in Winter season in 2010. All of them are located in the southern parts of the study area. Thangachimadam (74) and Pamban (63) PHCs share about nearly 80% of the incidence in this season. Other 11 PHCs have less than 10 malaria cases during this season (Fig. 5.1). It is to be noted that Thangachimadam did not report any malaria case in winter season of 2001.

Table 2
PHC Service Area - Coastal Blocks of Ramanathapuram District
Seasonal Pattern of Malaria Cases 2001 – 2010

Years	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Winter (%)	5.6	8.5	21.8	7	23.2	10.7	8.1	14.1	16.5	5.3
Pre-Monsoon (%)	13	18.7	34.3	21.1	30.2	21	29.8	20.9	25.2	17
Monsoon (%)	60	41.3	28.8	23.8	31.6	43.3	38.5	38.7	37	44.5
Post-Monsoon (%)	21.6	31.6	15.1	48.1	15	24.9	23.7	26.3	21.2	33.2

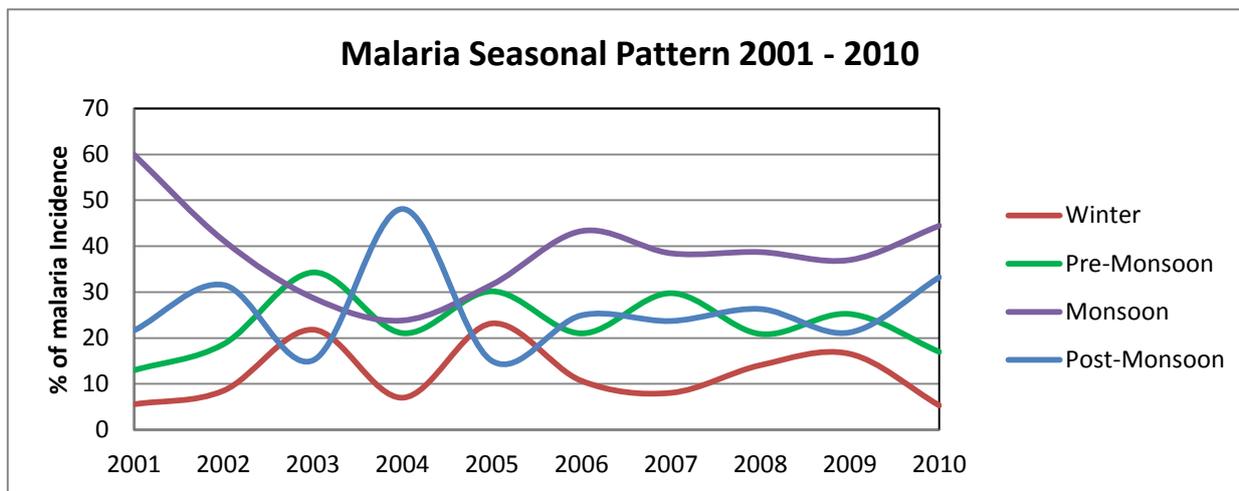


Fig 4

During the Pre-Monsoon period in 2010, 17% of the malaria cases occurred. Only 15 PHCs had malaria cases. Of these 15 PHCs, those in the Rameswaram island alone share 80% of the incidence. Tirupullani (23), Uchipuli (20), Mandapam (13), Valanur (12), Periyapattinam (11) and Erwadi (10) PHCs have a moderate incidence. Other one-fourth of the PHCs have less than 10 malaria cases each (Fig 5.1).

During the Monsoon period 65% of the PHCs have malaria incidence in 2010. Pamban (435) alone has an extremely higher number of malaria cases which accounts for about 30% of the seasonal total cases in this season. Thangachimadam (283), Uchipuli (195) and Mandapam (148) PHCs also have a higher incidence. All these are located in the Mandapam block along with Pamban (Fig. 5.2). It is to be noted that during this season incidence area extended from the coastal PHCs towards the interior PHC areas. S.P.Pattinam of Tiruvadanaai black had one malaria case during this season only. It is interesting to note that Appanur, Melasirupothu, Sayalkudi and Uchinatham PHCs did not have any malaria case in this season of maximum incidence. These four PHCs had malaria only during the other seasons.

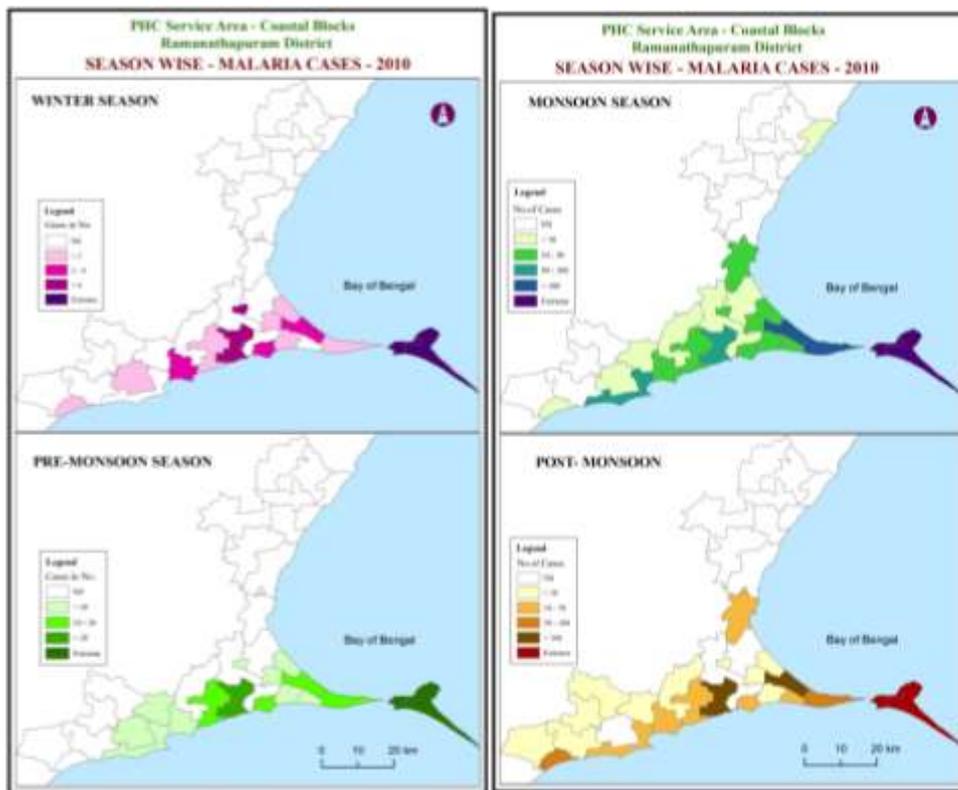


Fig (5.1) & (5.2)

As already noted, Post-monsoon period is the period of maximum rainfall for the study area. Out of 34 PHCs, malaria cases reported only in 21 PHCs in 2010 (Fig. 5.2). Here also Thangachimadam (273) and Pamban (267) account for about 54% of the total malaria cases. Tirupullani (122), Uchipuli (101) and Mandapam (94) PHCs also have a higher incidence (Table 5.2).

Changes between 2001 and 2010

- 1) Pamban PHC ranked first in Post-monsoon as well as monsoon season in 2001. However, in 2010 Pamban retained first rank only in monsoon season. Thangachimadam PHC had a higher incidence of malaria in the Post-monsoon season of 2010. During Winter and Pre-monsoon also, these two PHCs shared first and second rank among themselves during this study period.
- 2) Seasonally Monsoon period has a higher number of malaria cases followed by Post-Monsoon period, Pre-monsoon period and winter season.
- 3) Almost all the coastal PHCs which are located along the Gulf of Mannar coast have malaria incidence during all seasons.
- 4) During the Monsoon and Post-monsoon periods incidence of malaria extends to the interior PHCs.

In All the seasons Thangachimadam (74) and Pamban (63) PHCs (both are located in Rameswaram island) alone share about more than 80% of the incidence. There are two IMD weather stations in Ramanathapuram district, among the two Pamban is located in the study area where in Island. Rameswaram island consist two PHCs (Thangachimadam and Pamban) so, it's better to analyse Rameswaram Island for the climatic variables and the its effect on malaria diseases.

Trend of Malaria Cases in Rameswaram Island

In the present study, the API index shown from 2001 to 2010 is fluctuating. However, after 2005 the API score has shown a decreasing trend. The maximum cases occurred in 2003 and 2005 whereas the minimum cases are found in 2001 (Fig.6). API index of Pamban PHC rose in 2002 and declined till 2009 and rose again to 2010. Thangachimadam PHC also has shown the same trend of Pamban.

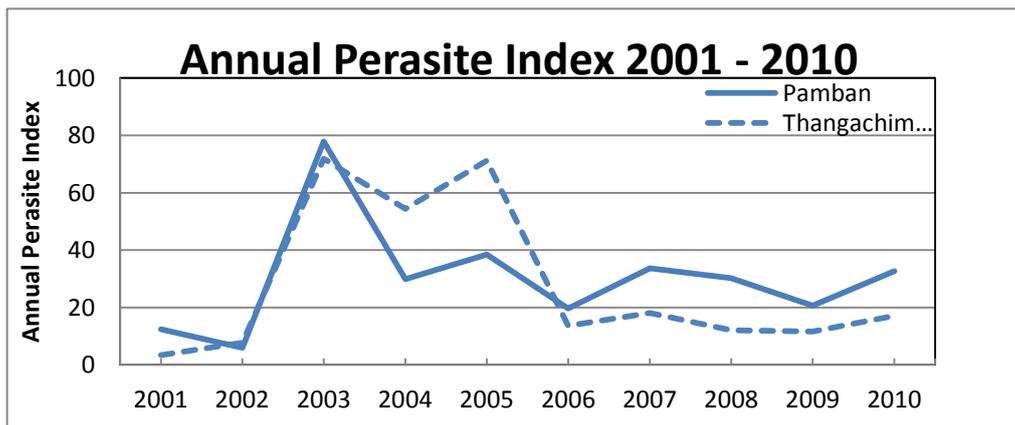


Fig 6

Climatic variables and Malaria vectors in Rameswaram Island

The Rameswaram Island, with a mean annual temperature of 32°C and a mean annual rainfall of 89mm, enjoys both the Northeast and the Southwest monsoon. The monsoon extends from June over a period of 3 months, whereas the Northeast monsoon commences in mid-October and ceases in December. With the onset of the Southeast monsoon the Gulf of Mannar becomes rough and choppy, while the Palk Bay is calm. During the North-East monsoon these conditions are reversed.

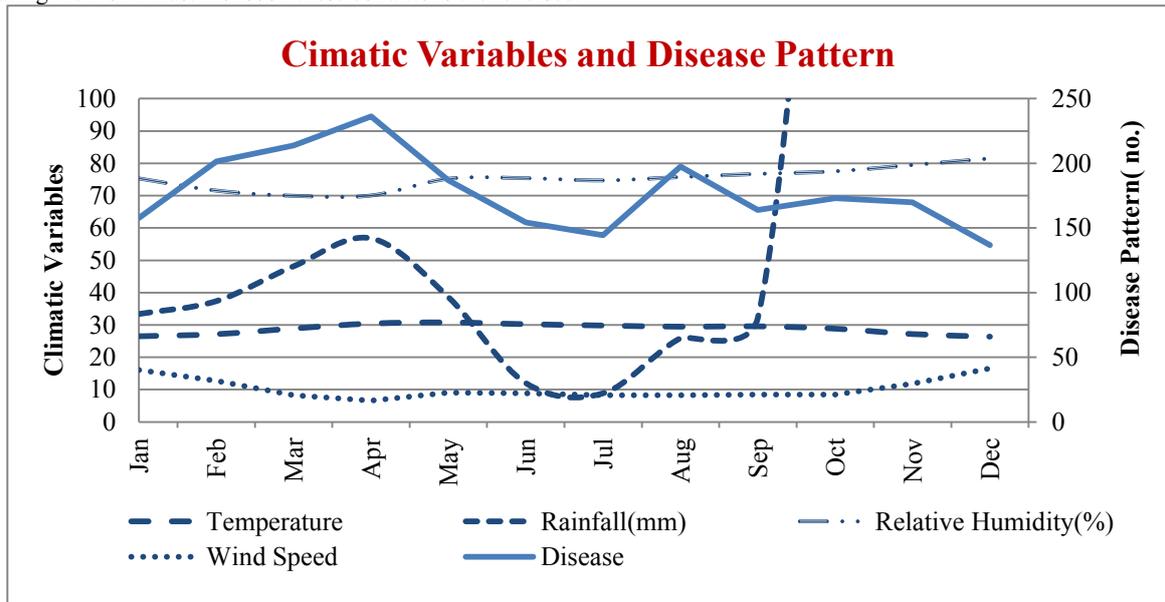


Fig 7

III. ANALYSIS

For most *Anopheles* vector species of malaria, the optimal temperature range for their development lies within 20°C to 30°C. However, transmission of *P. vivax* requires a minimum average temperature of 20°C and transmission by *P. falciparum*, requires a minimum temperature of 24°C. The transmission window in terms of the temperature range should extend over a period of time for completion of the sporogony. Malarial survival is also dependent on the time of the year, i.e. the wet or dry season. However, no clear relationship has been observed between the positive malaria cases and the annual precipitation. Some actually contend that the amount of rainfall may be secondary in its effects on malaria to the number of rainy days or the degree of wetness that exists after a rain event. Also, if the average monthly relative humidity is below 70 per cent and above 80 per cent the life span of the mosquito gets so shortened that the scope of malaria transmission diminishes. Positive cases of malaria are reported throughout the year, as a right combination of average temperature, rainfall and precipitation conditions persists across the country over all the seasons in some part or the other. To establish the conditions conducive to malaria transmission, the 10-year average monthly temperature, relative humidity, wind and precipitation covering the period 2001 to 2010 taken from IMD were plotted against the average all India monthly malarial cases reported for the same period. It is noted that the average relative humidity range (70 to 80 per cent) remains conducive to malaria transmission, only between the months of February to August, which coincides with the maximum number of positive malarial cases reported during this period (fig. 7). Meanwhile, the average temperature remains between the ranges of 25 to 30°C throughout the year, i.e. from January to December, which falls within the temperature transmission window of malaria.

Though only during October to December a substantial amount of rainfall is recorded, but the malarial cases still persist in the months when the average rainfall is almost nil. This further strengthens the observations of researchers cited earlier in this paper, that rainfall and numbers of malaria cases do not have a direct correlation. Though the broad malaria transmission window in terms of temperature is between 25 and 30°C, the number of days required for a vector to complete its cycle varies according to the number of days a particular range of temperature persists provided the relative humidity remains conducive. For example, it has been observed in Coastal Areas, that the *P. vivax* vector requires 15 to 25 days to complete its cycle if the temperature remains within 20°C to 25°C, and its life cycle may get completed even within 6 to 10 days, if the temperature range remains within 25°C to 30°C. In both the cases the relative humidity remains within 70 to 80 per cent. Considering this as a lead, an attempt was made to extract the number of days when positive malarial cases reported within a particular temperature range and relative humidity. This was done by simultaneously scanning daily values of temperature, humidity and the reported *P. falciparum* and *P. vivax* cases for the period May to October when the average relative humidity on a national level remains within 55 to 80 per cent. The analysis was carried out for the period 1995 to 2000. It was identified that for *P. vivax*, on average, the humidity levels remained between 55 and 80 per cent in the May to October period for 15 to 20 days when the temperature fluctuated between 15 and 20°C; for 10 to 20 days when the temperature fluctuated between 20 and 25°C and for 6 to 10 days when the temperature fluctuated between 25 to 30°C. Similarly, for *P. falciparum* the humidity remained between 55 and 80 per cent when the temperature varied between 20 and 25°C for 20 to 30 days, between 25 and 30°C for 15 to 25 days and between 30 and 35°C between 8 and 12 days respectively. The absolute value of temperature increases, the number of days that the temperature remains within each range decreases, therefore the time for which the vector thrives also decreases with increase in temperature. This conclusion is likely to have a significant effect under the projected climate change scenario for coastal region when the temperatures are to increase by 2–4°C with respect to the current climate.

A large number of studies also relate El Niño Southern Oscillation (ENSO) to malaria epidemics. Our analysis for the period 2001–2010 at the national level indicates that if the number of incidences in a particular year is less than the decadal average, then for that year incidences are influenced by La-Nina. On the other hand, when the number of incidences in a particular year exceeds the decadal average, then the incidences of this particular year are influenced by El-Nino (Figure 8). El-Nino and La-Nino years are also year's which coincide with deficit and excess rainfall years, but all excess and deficit rainfall years are not El-Nino or La-Nina years. Though there is a general tendency for the malaria incidences also to coincide with droughts and floods, however, the separation is not as good as that is observed in case of El Nino/La Nina events.

Table 3
Decadal Average of Climatic Variables

43363 PAMBAN						
YEAR	MMAX	MMIN	TMRF	MSLP	RH	AWS
1980	31.5	25.6	77.6	1007.1	73.3	13.8
1990	32.0	26.0	75.4	1007.2	72.5	12.8
2000	32.3	26.1	73.2	1007.3	72.6	12.0
2010	31.8	25.9	82.5	1007.5	74.9	10.3

Source: IMD, Pune.



Fig 8

An examination of the correlation coefficients between the detrended malaria incidence series for current year and for previous year with respect to year of malaria incidence and seasonal rainfall shows that the rainfall over few subdivisions in previous April as well as in August of the current year has strong bearing on malaria incidences (Table.1). Rainfall during October over island is positively correlated with malaria incidences in following year in these areas (with correlation coefficient, 0.52). This is because the rainfall in October in the previous year creates favourable conditions for a good vegetation growth and hence retention of optimum humidity conditions required for breeding of the mosquitoes in the subsequent year. If the rainfall in November in the current year is high, it will wipe out the breeding of mosquitoes and in turn decreases the cases of malaria in these areas during the peak season of incidences between the decadal averages of climatic variables. It may be noticed that the mean maximum temperature and mean minimum temperature have an increasing trend. Total monthly rainfall also has increased; it consequently increases relative humidity. It to be noted that the average wind speed has decreasing which may increase the malaria incidence within the island. Fig. 4 shows the relationship between malaria incidence and the El Nino years, and it indicates that malaria incidence has increased in the post-El Nino year.

IV. CONCLUSION

Considering the present endemic nature of malaria in India, this study assesses the climate parameters governing current malaria transmission in India and the likely extent of malarial activity in the future due to climate variables. This study indicates the dominant role of temperature, relative humidity, rainfall and Wind speed in malaria transmission. Temperature, rain fall, humidity are in increasing trend while Wind Speed has in decreasing trend. Added together, they provide a favourable environment for breeding of mosquitoes leading to an increased incidence of malaria.

The research results presented here, *vis-à-vis* the relationship between malaria and its climate determinants. The extent of vulnerability due to malaria also depends on determinants other than the climate such as environmental factors, the parasite development rates, the vector population, and the prevailing socio-economic conditions and hence the adaptive capacity of the human population too. Therefore, an integrated research is required for a better assessment of malaria transmission under the future climate change scenario Occurrence of El Nino maybe an alarm for taking precautions for the succeeding year. Hence awareness about this is to be created among the resident population in the study area.

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