Predicting high-risk years for malaria in Colombia using parameters of El Niño Southern Oscillation

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Summary

The interannual variation in malaria cases in Colombia between 1960 and 1992 shows a close association with a periodic climatic phenomenon known as El Niño Southern Oscillation (ENSO). Compared with other years, malaria cases increased by 17.3% during a Niño year and by 35.1% in the post-Niño year. The annual total number of malaria cases is also strongly correlated ($r = 0.62$, $P < 0.001$) with sea surface temperature (SST) anomalies in the eastern equatorial Pacific, a principal parameter of ENSO. The strong relation between malaria and ENSO in Colombia can be used to predict high and low-risk years for malaria with sufficient time to mobilize resources to reduce the impact of epidemics. In view of the current El Niño conditions, we anticipate an increase in malaria cases in Colombia in 1998. Further studies to elucidate the mechanisms which underlie the association are required. As Colombia has a wide range of climatic conditions, regional studies relating climate and vector ecology to malaria incidence may further improve an ENSO-based early warning system. Predicting malaria risk associated with ENSO and related climate variables may also serve as a short-term analogue for predicting longer-term effects posed by global climate change.

Keywords
Malaria, Colombia, El Niño, ENSO, early warning system.

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Introduction

El Niño Southern Oscillation (ENSO) is a periodic climatic phenomenon which affects weather patterns in certain parts of the world including South America (Ropelewski & Halpert 1987; Poveda & Mesa 1997). This 4–6 year oscillation has two extremes known as El Niño or warm events and, less frequently, La Niña, or cold events. In each cycle the El Niño extreme may last for 1 or 2 years and is associated with warmer than average sea surface temperature (SST) in the eastern equatorial Pacific Ocean. An analysis of historical malaria epidemics on the Indian subcontinent showed a relative risk of 3.6 for an epidemic in El Niño years in Sri Lanka, and a relative risk of 4.5 for a ‘post-Niño’ year in the former Punjab province of India (Bouma & van der Kaay 1996). Geographical associations between ENSO-affected areas and malaria epidemics were also apparent in other parts of the world, including the north coast of South America (Bouma et al. 1994; Poveda & Rojas 1996), which experiences relatively dry conditions during El Niño years (Ropelewski & Halpert 1987).

Before the introduction of intensive vector control measures, recurrent malaria epidemics in Surinam and Venezuela occurred about every 5 years—a cycle that Gabaldon (1949) called ‘paraquinquennial periodicity.’ In recent decades the reliance on residual insecticides has
decreased and malaria has again become a serious health problem. In Venezuela, the periodic nature of malaria is also evident, and shows a strong association with ENSO (Bouma & Dye submitted). As with malaria epidemics in the Punjab, data for Venezuela show a large increase in malaria cases (+37%) in the year following an El Niño event. The ability to predict years of high and low risk for malaria can be used to improve epidemic preparedness. We investigate the relation between ENSO and malaria in bordering Colombia which is the most malarious country in the North Andean region (Haworth 1988).

**Area and methods**

The climate of Colombia is extremely variable. Mean annual precipitation ranges from less than 50 mm in parts of the Caribbean coast to over 13 000 mm in areas on the Pacific coast. The range of altitudes (0–5000 m) is responsible for considerable variation in ambient temperatures, and over 50% of the population inhabit the cooler areas above 1000 m. The 1994 census shows that of Colombia’s 32.5 million inhabitants, an estimated two thirds live in areas endemic for malaria (Rojas et al. 1992). Between 1983 & 1992, the average incidence of malaria was 5.04 per 1000 per year, although rates varied considerably between years. Transmission is seasonal in the highland areas of Magdalena, Norte de Santander, Santander, Boyaca, Cundinamarca, Caldas, Tolima, Cauca, Huila, Nariño and Caqueta (Haworth 1988), suggesting that temperature is a principal limiting factor in the epidemiology of malaria. Several malaria vectors have been identified in Colombia, of which the most important are *Anopheles albimanus*, *A. darlingi* and *A. nuñezrovairi* (Quiñones et al. 1987). Both *Plasmodium falciparum* and *P. vivax* are transmitted in Colombia, with *P. malariae* being only rarely recorded (Haworth 1988). Data for 1960–92 show that 46.5% of malaria infections are caused by *P. falciparum*.

![Figure 1](https://example.com/figure1.png)

In looking for associations between ENSO and interannual variations in malaria incidence in Colombia we examined the total number of confirmed (microscopically diagnosed) malaria cases reported in the country by the National Institute of Health between 1960 and 1992. The 5-year moving average was used to remove the observed systematic trend of increasing malaria cases over this period, which is likely to be a product of reduced reliance on insecticides and increasing drug resistance, as well as natural increase in the population at risk during this period. The deviation from the trend was expressed as a percentage of the ratio of the residual number of cases and the number of cases given by the trend for that year.

Between 1960 & 1992, 6 El Niño events were recorded, occurring in 1965, 1972–73, 1976, 1982–3, 1987 and 1991–4. Some El Niño events last for more than 1 year, so in our notation ‘Niño°’ refers to the first reported El Niño year, while ‘Niño⁺+’ refers to the following year, regardless of whether this is a second El Niño year or a post-Niño year. We used analysis of variance (ANOVA) to test whether malaria during Niño°, Niño⁺+ and other years was significantly different. As the choice of El Niño years is somewhat arbitrary (we excluded the Niño years for which there is no consensus: 1963, 1969 and 1979), we also correlated annual malaria cases with one of ENSO’s quantitative parameters, SST anomalies for the eastern equatorial Pacific. These anomalies are deviations from the average SST in the Pacific in the area between 20°N and 20°S and 170°E–American coast (Figure 1), as described and provided by Parker et al. (1994).

**Results**

The annual number of reported malaria cases in Colombia (1960–92) is shown in Figure 2, together with the 5-year moving average. There is a very clear increasing trend in the number of cases over the 32-year period and reasons for this are discussed later. Over and above this trend, it can be seen that in El Niño years (Niño°) and in the year immediately following an El Niño (Niño⁺+), the number of malaria cases is usually higher than the 5-year moving average, whereas in other years there is a general deficit of cases relative to the moving average.

![Figure 2](image-url)
The bar chart in Figure 3 shows the average deviation from the trend (as a percentage) during the six Niño° years ( ■), Niño+1 years ( ▲) and 21 other years between 1960 and 1992.

Figure 3 Average percentage deviation in malaria cases (with standard error bars) from the trend during 6 Niño° years ( ■), Niño+1 years ( ▲) and 21 other years between 1960 and 1992.

Discussion

The variability of Colombian malaria cases between years shows a striking association with the El Niño Southern Oscillation. Sea surface temperature anomalies in the eastern equatorial Pacific in the first months of the year enable prediction of malaria that year. The slightly weaker correlation for SST anomalies in the preceding October–December period can also be used for predicting malaria in the following year, allowing more time to prepare an epidemic response. As the highest-risk years tend to follow El Niño events, each occurrence of an El Niño gives at least 1 year warning to mobilize resources in preparation for a high-risk year.

This may include alerting medical staff, optimizing drug supplies, and planning and implementing additional vector control measures. The fact that increasing reliability of forecasts for El Niño events with lead times of up to 1 year (Chen et al. 1995) also offers scope for anticipating the less pronounced risk of epidemics associated with El Niño years themselves. In view of the current developing El Niño in 1997, our findings suggest that 1998 will be a high-risk Niño+1 year and figures for average January-March SST anomalies from the eastern equatorial Pacific for October-December 1997, and January-March in 1998 may provide quantitative confirmation of this.

The mechanisms by which ENSO and related climate variables affect malaria transmission in Colombia are not clear. Both Colombia and neighbouring Venezuela share the Niño° year as highest-risk year (+35.1% and +37%, respectively), for which we have proposed an ecological explanation (Bouma & Dye 1997). In Venezuela, the Niño° is a low-risk year in contrast to Colombia, where the Niño° year is associated with increased risk.
lives at an altitude above 1200 m, higher temperatures during El Niño years (Pulwarty 1994) may facilitate malaria transmission by shortening the extrinsic cycle of the parasite in the vector (i.e. the time it takes for the parasite to become infective).

Region-based ecological, entomological and epidemiological studies are needed to elucidate the relationship between El Niño and malaria incidence in highland and lowland areas. Regional studies may also yield more robust indicators to predict local epidemics. Further studies on the impact of local climate variability (not exclusively ENSO-related) on disease, particularly of geographical shifts in malaria distribution in the highlands, are likely to improve the accuracy of the assessment of the effects of global climate change.

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References

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