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Global malaria maps and climate change: a focus on East African highlands

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Given the well documented climate sensitivity of malaria, the potential implications of global change have given rise to much speculation and controversy [1–5]. Because of the plethora of other parameters determining malaria morbidity and mortality, the extent to which climate change amplifies transmission remains a crucial question. Recent efforts to globally map malaria based on interpolated prevalence figures offer much needed help to guide and evaluate control, and an improved quantitative framework to describe distributional change [1]. Mapmakers have now used global prevalence estimates to show the shrinking distribution and intensity of malaria in the 20th century, and to argue that the magnitude of the effects of control and economic development associated with this decline areorder(s) of magnitude greater than the possible effects of climate change, concluding that the hold of climate on the disease has waned [1]. We here ask whether this conclusion applies to the heavily populated highlands of East Africa, regions of the globe that have been at the center of the debate on the impact of temperature warming [3]. For these regions, the methodology used for interpolating data [1] appears to eliminate the existing temperature–malaria relation when survey data are sparse. This has important implications for the relevant resolution at which to address the role of warmer temperatures in regions with sharp climate variations, and for the need to include temperature in the statistical models that estimate malaria prevalence in highland regions.

In countries where malaria is endemic, areas at higher elevations are potentially most vulnerable to the effects of climate change [2–4], as temperature generally decreases with higher altitude, reducing vector abundance [6] and the development rate of the parasite [7]. The ‘malaria lapse rate,’ a pattern of declining prevalence with altitude, remains one of the most striking characteristics of malaria epidemiology [3]. Intuitively, altitude is a local proxy for temperature that also integrates the effects of rainfall. Figure 1 shows that this temperature-dependent pattern is typically absent in the interpolated prevalence estimates of the malaria maps [1] for highland regions of East Africa. Given the central relevance of temperature to climate change, we need to ask whether the ‘malaria lapse rate’ pattern is lost in the estimated prevalence maps because the estimates ‘smooth’ the variation of prevalence with altitude, or the pattern is no longer present in the survey data itself. Although we do not have access to the full survey data itself, we can rely on the country-level maps illustrating the spatial distribution of the surveys to compare estimated prevalence for the only region in Kenya for which the surveys exhibit high coverage, to those in a nearby region where coverage is lower, and to those in the higher altitude part of the country (Figure 1). Where the number of survey points is high, the estimated prevalence should closely reflect the survey data itself. The key comparison in the figure is that between the estimates of prevalence for sub-regions that differ in the density of surveys (red to yellow and green, in Figure 1a. This comparison suggests that the statistical model underlying the prevalence estimates used in the maps does indeed smooth temperature effects. The strong association between malaria and altitude in the interpolated figures for areas with a high density of surveys is comparable to that for the available survey data from past publications (Figure 1). This suggests that even the more extensive control of malaria over the past decade has not eliminated the effects of altitude, and that there is significant vulnerability of highland malaria to current rising temperatures.

The impressive results of malaria control in higher latitudes do not easily transfer to tropical Africa where longer lived and more anthropophilic vectors can be orders of magnitude more efficient in transmitting malaria [12]; this significantly limits the extrapolation to the tropics of the ‘decoupling’ between climate and malaria that has been observed in higher latitudes. Malaria is a disease of poverty, and given ample resources, control will remove all pre-intervention determinants of the disease, including climate. Crucially, a raised malarious potential in highland regions will require sustained levels of control that require increased resources and undiminished efficacy of drugs and insecticides to limit the enhanced effects of climate warming. In Ethiopia, Kenya and Tanzania alone, around 73 million people live in the vulnerable altitude between 1000 and 2500 m (this represented 66% of the total population of the region in 2000).

We suggest that analyses of climate versus control for regions with sharp climate variations would benefit from smaller regional scales and higher resolutions that explicitly consider temperature gradients; global analyses will tend to misrepresent changes in malaria prevalence in these often crucial regions. In particular, in regions where survey data are sparse, mapping of malaria could benefit from including temperature explicitly in the statistical

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mapping model, as has been the custom in producing the less computationally demanding global malaria maps of the past century.

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