Supplementary Information

A: The weakening geographical relationship between climate and malaria endemicity 1900-2007

Temperature and rainfall are two climatic variables known to assert fundamental influence on local environmental suitability for malaria transmission, through effects on vector and parasite longevity and reproduction[1]. A 0.5° x 0.5° (approx. 55 x 55 km at the equator) spatial resolution gridded climatology[2] was used to create mean temperature and rainfall surfaces. The climatology is created by interpolating meteorological station data for the period 1901 to 2002 to create monthly surfaces which can be averaged temporally to create synoptic annual means. These synoptic temperature and rainfall surfaces were imported into a geographical information system (ArcGIS 9.2, ESRI Inc, Redlands CA, USA) and overlaid using a common projection (geographic projection using the Clarke 1866 datum). The centroid position of each 0.5° x 0.5° climatology pixel was defined and converted into a set of point locations. These point locations were then used to extract class membership values from the historical (c. 1900) Lysenko[3] and contemporary 2007[4] endemicity surfaces within the GIS. This procedure resulted in four values (synoptic annual mean temperature and rainfall, and malaria endemicity class as defined by Lysenko and by the contemporary surface) for every 0.5° x 0.5° pixel across the Earth's land surface (67,421 locations). No values were extracted for Antarctica. Extracted values were then imported into the R software package[5] and boxplots were generated to summarise the distribution (0.1, 0.25, 0.5 (median), 0.75, and 0.9 quantiles) of the rainfall and temperature climatology variables within regions stratified by endemicity class as defined by Lysenko and by the contemporary endemicity map.

When the climate variables were aggregated according to the historical malaria endemicity strata, a monotonic trend was observed for both variables: each successively higher class of endemicity was associated with increasing temperatures and rainfall (Fig. S1, left column), consistent with theoretical relationships between malaria transmission and climate in non-intervention settings[1]. These relationships all but disappear, however, when the contemporary endemicity map is compared with the same climatology (Fig. S1, right column). This simple observation illustrates that these two key climatic drivers of environmental suitability for malaria have little explanatory power when analysed against a distribution significantly reduced from the hypothesised fundamental niche[6] of the species and with an endemic level modified extensively and non-uniformly by control and development across the globe. These analyses were repeated using averaged 1900-1921 and 1980-2001 climatologies with the historical and contemporary malaria distributions, respectively, and the resulting boxplots were almost identical (available on request).

B: Estimating changing endemicity in terms of PfR_0 effect size

The main manuscript (Fig. 1) presents maps showing the presumed historical (c. 1900) and modelled contemporary (2007) global endemicity of malaria, and the differences between the two maps, stratified into classes defined in units of parasite prevalence. The predicted land area covered by each endemicity class in 1900 and in 2007 is summarised in Table S1.In order to compare the observed changes in endemicity between these time periods with hypothesised changes due to climate change and modelled or observed changes due to contemporary control measures, it was necessary to translate both maps into approximate units of PfR_0, the *P. falciparum* basic reproductive number. The Methods section explains the use of a simple *P. falciparum* transmission model to estimate a value of PfR_0 corresponding to the mid-value of each endemicity class. The converted values, and magnitude of transitions between classes are summarised in Table S2.

Using these conversion values, maps of PfR_0 were made corresponding to both historical (Fig. S2a) and contemporary (Fig. S2b) endemicity. These two maps were overlaid in a geographical information system (GIS) (ArcGIS 9.2, ESRI Inc, Redlands CA, USA) and the relative change in PfR_0 between the historic and contemporary map was calculated for each 5 × 5 km pixel. These relative changes were summarised as either areas of increase; areas of no change; and areas of decrease of between zero and one, one and two and greater than two orders of magnitude (Fig. S2c). The land area represented by each class was then calculated in the GIS by reprojecting the maps to an equal-area projection (Mollweide projection), and then summarised as a fraction of the historically endemic world, i.e. all areas with a positive PfR_0 in 1900 (Table S3).

Supplementary References

[1] Craig, M., Snow, R. W., & Le Sueur, D. A climate-based distribution model of malaria transmission in Sub-Saharan Africa. *Parasitol. Today* **15**, 105-111 (1999).

[2] Mitchell, T. D. & Jones, P. D. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *Int. J. Climatol.* **25**, 693-712 (2005).

[3] Lysenko, A. J. & Semashko, I. N. Geography of malaria. A medico-geographic profile of an ancient disease [in Russian], in *Itogi Nauki: Medicinskaja Geografija* (ed A. W. Lebedew) 25-146 (Academy of Sciences, Moscow, 1968).

[4] Hay, S. I., *et al.* A world malaria map: *Plasmodium falciparum* endemicity in 2007. *PLoS Med.* **6**, e1000048 (2009).

[5] R Development Core Team, *R: a language and environment for statistical computing* (R Foundation for Statistical Computing, URL: http://www.R-project.org, Vienna, Austria, 2009).

[6] Southwood, T. R. E. Habitat, templet for ecological strategies? Presidential address to British Ecological Society, 5 January 1977. *J. Anim. Ecol.* **46**, 337-365 (1977).

[7] Guerra, C. A., *et al.* The limits and intensity of *Plasmodium falciparum* transmission: implications for malaria control and elimination worldwide. *PLoS Med.* **5**, e38 (2008).

Supplementary Figures

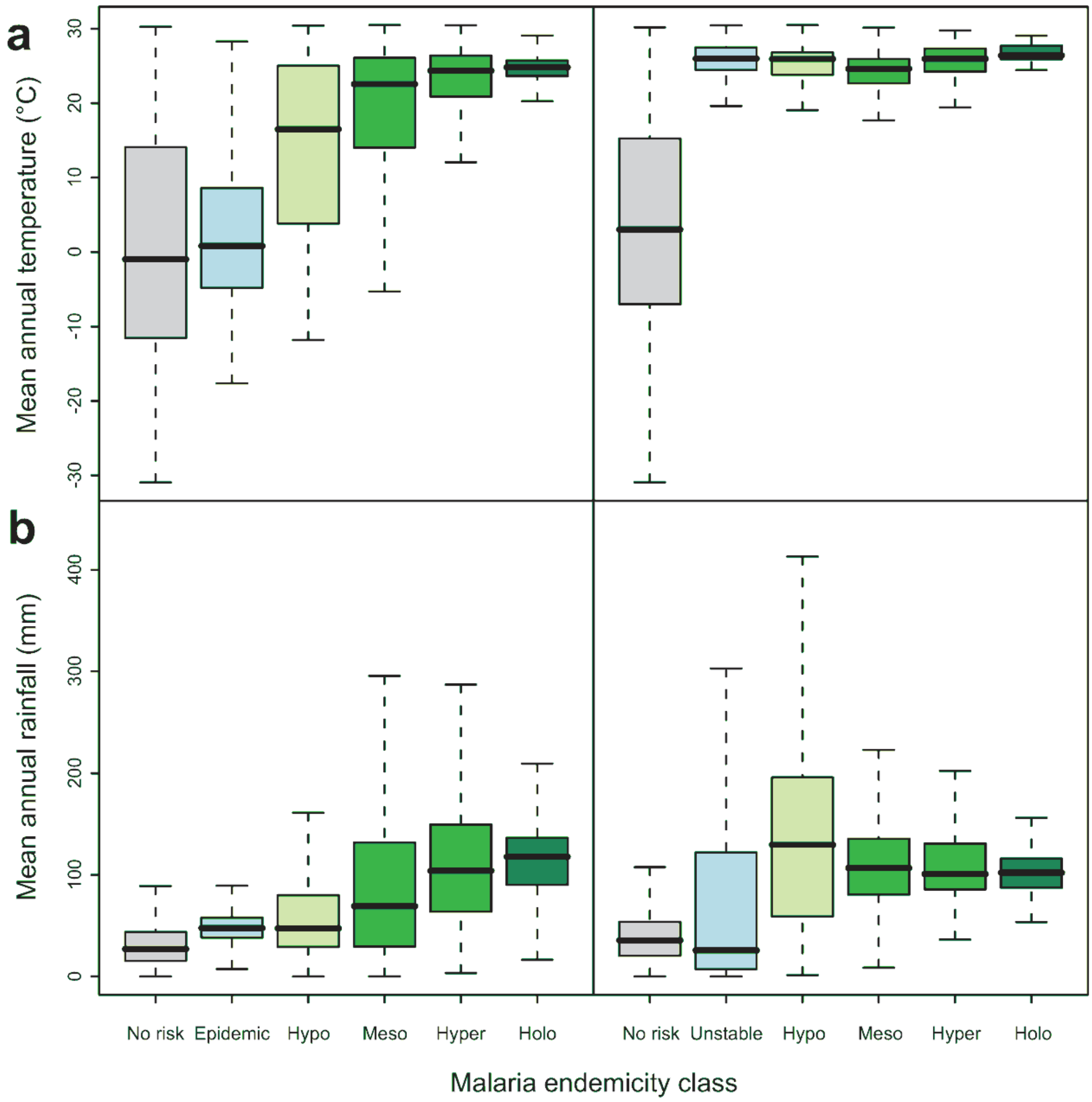

Figure S1. Characteristics of synoptic climatic variables in regions defined by different classes of malaria endemicity. Mean annual temperature (**a**) and rainfall (**b**) for period 1901 to 2002[2] stratified by endemicity class. Left panels: pre-intervention endemicity (c. 1900) as defined by Lysenko[3]; Right panels: Contemporary endemicity (2007) based on a recent global project to define the limits[7] and intensity of current *P. falciparum* transmission[4]. For each endemicity class, the distribution of temperature or rainfall values is summarised by the median (heavy line), inter-quartile range (coloured box), and the range of the 0.1 to 0.9 quartiles (outer bars).

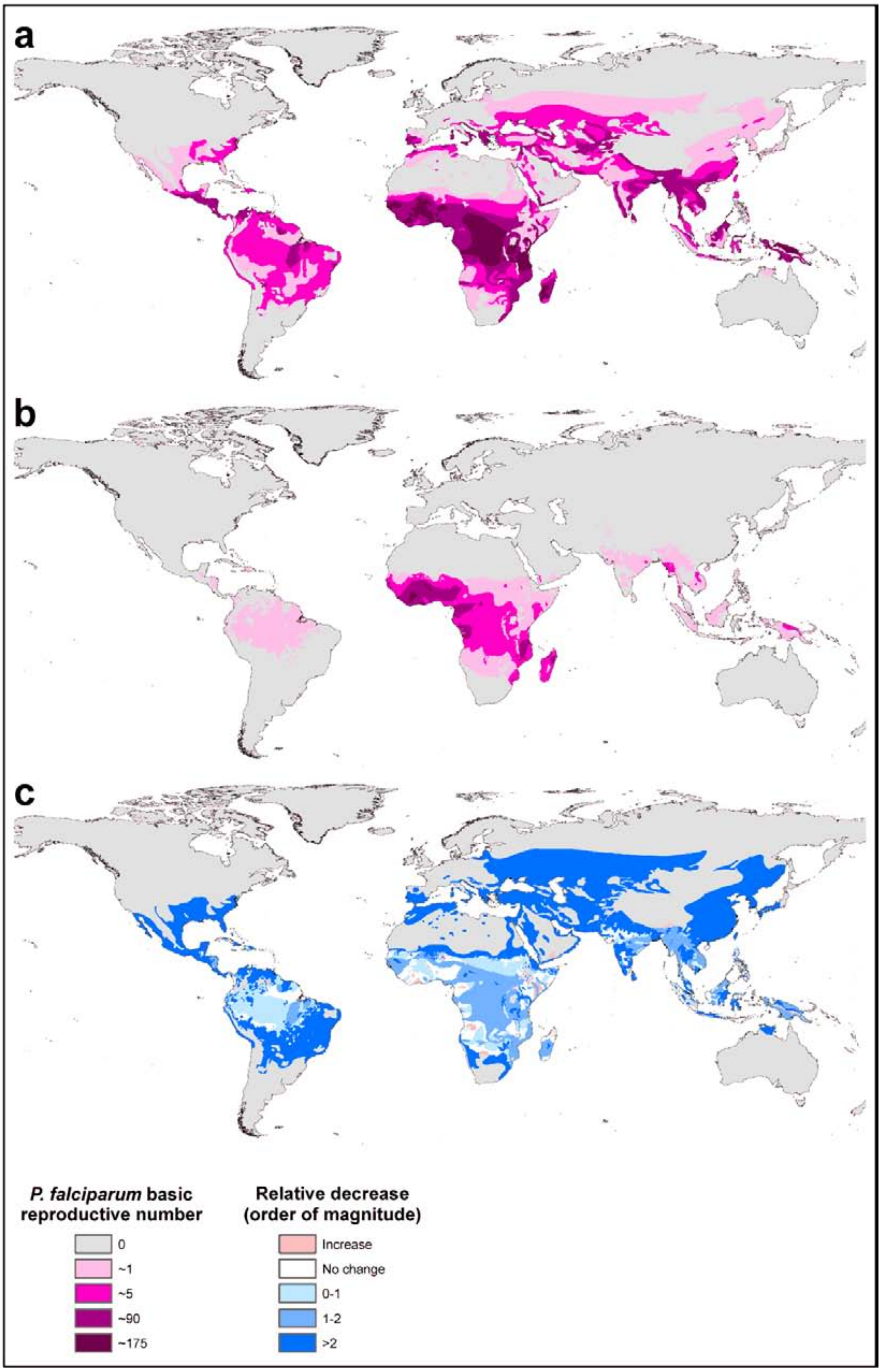

Figure S2. Maps estimating the *P. falciparum* basic reproductive, PfR0. Estimated values of PfR_0 corresponding to: (**a**) historical and (**b**) contemporary malaria endemicity classes, and (**c**) the magnitude of decrease between those two periods. See text for more details.

Supplementary Tables

Table S1 **The changing global area of malaria subdivided by endemicity class**

	Lysenko (c.1900)	Contemporary (2007)
	km^2 (%)$_1$	km^2 (%)$_1$
No risk	57.06 (42.35)	94.94 (70.45)
Epidemic / unstable	12.01 (8.91)	11.00 (8.16)
Hypoendemic	22.61 (16.78)	17.06 (12.66)
Mesoendemic	23.27 (17.27)	8.83 (6.55)
Hyperendemic	14.77 (10.96)	2.77 (2.06)
Holoendemic	5.03 (3.73)	0.15 (0.11)

1. Area figures are in millions and the percentage figures express the proportion of the total global land area occupied by that endemicity class. All values exclude Antarctica.

Table S2 **Conversion of endemicity classes (PR) into R_0 and magnitude of change associated with transitions between historic and contemporary classes**

Lysenko endemicity class		Hypo	Meso	Hyper	Holo
PR (centre value)		5%	30%	63%	88%
R_0 equivalent		1.3	5.5	87.7	175.6
Proportional changes in R_0 associated with transitions from historical (columns) to contemporary (rows) endemicity classes. Parentheses show order of magnitude of change	Hypo	- (-)	÷ 4.2 (0-1)	÷ 67.4 (1-2)	÷ 135.0 (2-3)
	Meso	× 4.2 (0-1)	- (-)	÷ 15.9 (1-2)	÷ 31.8 (1-2)
	Hyper	× 67.4 (1-2)	× 15.9 (1-2)	- (-)	÷ 2.0 (0-1)
	Holo	× 135.0 (2-3)	× 31.8 (1-2)	× 2.0 (0-1)	- (-)

Table S3 **Global land area associated with different magnitude changes in $\boldsymbol{PfR_0}$ between 1900 and 2007.**

Change in PfR_0 1900 - 2007	Area ('000 km^2)	Proportion of 1900 endemic world
Increase	1,371	2%
No change	7,041	11%
Decrease 0-1 orders of magnitude	8,043	12%
Decrease 1-2 orders of magnitude	12,009	18%
Decrease >2 orders of magnitude	38,096	57%