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Average Household Size and the Eradication of Malaria

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AVERAGE HOUSEHOLD SIZE AND THE ERADICATION OF MALARIA

CONTENTS

ABSTRACT

Efforts to eradicate malaria during the 20th century succeeded in some parts of the world but failed in others. Malaria also disappeared spontaneously in several countries for reasons that remain an enigma. The connection between malaria and poverty has long been noted. Here we focus on a specific aspect: household size, which has hitherto received little attention. We find strong evidence that when average household size drops below four persons, the probability of malaria eradication jumps dramatically and its incidence in the population drops significantly. This effect is independent of all commonly-studied explanatory variables and was globally valid across all climate zones irrespective of counter measures, vector species, or *Plasmodium* species. We propose an explanation based on the dispersal mechanism of the parasite. Malaria is transmitted at night by mosquito bite. The mosquito typically spreads the *Plasmodium* only locally over short distances to new human victims. To survive, the *Plasmodium* depends on infected humans making social contacts over longer distances. When household size decreases sufficiently, these contacts cross a threshold value that changes the balance between extinctions and replacements and the *Plasmodium* disappears on its own. We test this interpretation by contrasting our malaria model with dengue fever, which is also poverty-related and mosquito-borne but transmitted differently, namely through daytime exposure. Household size is uncorrelated with dengue incidence, whereas an indicator of outdoor work that is insignificant in the malaria model is highly significant for dengue. We conclude that poverty-induced malaria infection risks are likely to persist, but a focus on reducing effective household size can be a feasible and promising means of its eradication.

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Malaria, dengue fever, household size, DDT

JEL Codes
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1. Introduction

1.1 Malaria background

Malaria is a parasitic disease that is transmitted to humans by infected *Anopheles* mosquitoes. Long-range dispersal occurs when humans carry the disease to new areas and infect local *Anopheles* populations (Lum et al. 2007, Beklemishev 1959). The parasites (five different species of *Plasmodium*) infect red blood cells, causing anemia, nausea, fever and sometimes death. There are about 225 million cases of malaria infection annually and about 800 000 fatalities, of which 90 percent are in Africa, and most of which are children (Manguin et al. 2008).

Malaria is thought of today as a tropical disease, because that is where it remains prevalent, but historically it was present throughout the world, in all climate zones, from the coast of the Arctic Sea (up to 70° N latitude) and Siberia to tropical Africa (Lysenko and Kondraschin 1999, Reiter 2008, Huldén and Huldén 2009). Endemic malaria disappeared from Europe and North America during the 20th century and has been unable to re-establish itself there in spite of frequent annual importation of cases. So far no satisfactory or consistent explanation has been proposed for why some countries have managed to eradicate the disease while others have failed. Eradication cannot be achieved by vector eradication, that is by exterminating the population of the *Anopheles* mosquitoes which carry the *Plasmodium* infection. In fact, potential mosquito vectors are still present in 80 of the 82 countries in our data set where malaria has disappeared (see Appendix Table 1). Several other explanations for the eradication have been suggested, such as a change in the feeding pattern of the vector, draining of wetlands or intensive use of DDT (Hansen 1886, Wesenberg-Lund 1943, Snowden 2006, Kager 2002, Bruce-Chwatt and de Zulueta 1980). With respect to the latter, nearly three-quarters of the countries in our sample used DDT, for an average of over 15 years, yet malaria only disappeared in 43% of the countries.

This study examines household size as factor in malaria eradication. The connection between poor housing and malaria has only seldom been considered (Chagas 1925, Ackerknecht 1945). Many early scientists saw malaria as a social disease, which could be cured by mass-distribution of quinine and social reforms (reviewed by Bruce-Chwatt and de Zulueta 1980, Snowden 1999, Gachelin and Opinel 2011). But explanations have been lacking as to specific mechanisms by which why a vector-borne disease such as malaria is affected by poverty. Only one early author, Sidney Price James (1930), argued that the spread of malaria depended on the factors that brought the source, the carrier and the recipient into the necessary close association with one another. Therefore, he noted, the number of malaria cases was always higher in cottages in which big families slept together in one room, and that was especially the case among the poor. This explanation received little attention subsequently and the efforts concentrated on other factors such as mosquito control (Manguin et al. 2008, Gachelin and Opinel 2011). There are very few research articles that mention household size among parameters studied, and then mainly from malarial countries where the critical threshold value of four members never is observed (for instance see Hustache et al. 2007).

A recent analysis of the malaria trend in Finland over the interval 1750–2006 (Huldén and Huldén 2009) found that while many standard explanations of malaria disappearance did not have much explanatory power, mean household size appeared to correlate very closely over a long interval with the decline in malaria cases. In this study we expand the analysis to the global level, in the process testing James' early conjecture. Since there are no international statistics on the number of people sharing a bedroom, average household size is used. Data on malaria, vectors, demographic factors, sociological factors, and environmental factors for 232 countries or corresponding administrative units were compiled. 12 countries lacking data on average income, female literacy or population density were removed. Of the remaining 220 countries, malaria was never endemic in 32 countries, remains prevalent in 106 and has been eradicated from 82 countries. Thus indigenous malaria vectors (*Anopheles* species) are known from 188 countries, which is the sample for our analysis. Mongolia is the only country with indigenous vector species but no historical or recent malaria.

Although malaria was endemic in the Sub-Arctic, including in Yakutia where temperatures fell to -70° C during transmission season, it has been suggested that global warming might bring the disease back to Northern Europe (Kuhn et al. 2002). Bruce-Chwatt and de Zulueta (1980) showed that malaria disappeared from Europe during the 20th century, and other studies have pointed out that the disappearance of malaria from many countries has coincided with global warming after the end of the 19th century (Reiter 2008, Gething et al. 2010). Our analysis finds no explanatory role for climate, and instead points to socioeconomic factors.

We assembled a unique, detailed cross-sectional data set on our 188-country sample. Most variables are dated at the year 2000, due to lags in the availability of some data. Explanatory variables include GDP per capita, household size, female literacy, urbanization and slums, latitude, mean temperature, forest coverage, Muslim population, details of national DDT usage and population density (persons/km^2), as well as observations on 47 production commodities, to permit us to examine the role of outdoor working conditions.

We find that the larger is the mean household size, the lower the probability of eradication and the higher the national malaria incidence rate. However the coefficients appear to be insignificant in many specifications, and researchers could easily overlook the key effect. When household size enters the model, not as a continuous variable but as a dummy variable showing whether the national average household size is below four persons, the marginal probability of eradication jumps by 69 percent in absolute value and the effect becomes the most significant one in the model. This is observed even while controlling for income, female literacy, temperature, urbanization and other covariates. In a model of the national frequency of malaria infection we find the same pattern: household size only emerges as significant when modeled as a four-person threshold value, and in this form it is more significant than any other variable, including national per capita income. We also find significant effects for population growth, DDT usage and the Muslim fraction, the latter having an interesting connection with effective household size that we will discuss.

Our conjectured explanation of these results has to do with the malaria transmission mechanism. Practically all *Anopheles* mosquitoes feed at night (Becker et al. 2003). The mosquito female gets the infection from a human through a blood meal. After egg laying it returns to the same approximate location for another blood meal (Silver 2007). The parasite multiplies sexually in the mosquito. The process takes ~10–16 days and is completed when the infective form of the parasite reaches the salivary glands of the mosquito (Vaughan 2007). The process changes the behavior of the vector, making it bite more frequently and probe longer (Koella 1996). Early experiments with *Plasmodium vivax* showed that an infective mosquito will bite 30–40 times (James 1926). Therefore the more people who are sleeping in the same room the more people will be bitten, spreading the infection. As a way of testing our model, we re-do the analysis using data on the incidence of dengue fever, which is also spread by mosquitoes but by *Aedes* species that are active during the day (de Castro et al. 2005, Lambrechts et al. 2010). Its transmission mechanism is not expected to be sensitive to household size, but to factors affecting outdoor exposure. In the dengue case the household size variable becomes small and insignificant, as does income. Water availability and average cassava production, which are both insignificant for malaria, are significant for dengue. Cassava is a common cash crop that must be manually harvested using labour-intensive outdoor methods, implying greater exposure to diseases transmitted during the daytime. The contrasting dengue results add support to the view that average household size is a key variable determining the spread of malaria and the prospects of its eradication.

1.2 INSTRUMENTING THE DDT EFFECT

We assembled data for each country on the year DDT was introduced for malaria vector control, the year it was discontinued, and the number of years of actual use, which did not always coincide with the number of years between introduction and discontinuation. However, entering a DDT-related measure into our regressions leads to an endogeneity problem. The only countries that use DDT in malaria vector control are those that have malaria, so the presence of malaria strongly predicts the use of DDT. If we naively put a DDT usage measure into a regression with malaria incidence as the dependent variable we get an apparently high significance attached to a coefficient suggesting that DDT causes malaria.[1]

To remedy this we use a two stage estimator in which DDT is represented by an instrument based on strictly exogenous factors. One variable with an exogenous component is the decision of a country to ignore the US ban. In 1971 the United States enacted a ban on the production and use of DDT, a decision that likely could not have been foreseen by countries using DDT up to that

[1] Malaria campaigns with indoor spraying of DDT also affected other mosquitoes. *Aedes aegypti*, which is the main vector for dengue virus, was almost eliminated in Taiwan during the malaria eradication campaigns after WWII, and Taiwan was spared the epidemic of dengue transmission over 1945–1981 (Lambrechts et al. 2010)

point. About 40 percent of the countries in our sample apparently chose to ignore this action and continued using DDT up to 36 years later. We constructed a variable (*ddt_yban*) counting the number of years after 1971 that a country used DDT. We then used a Tobit regression (see Section 3.2) to explain *ddt_yban* using strictly exogenous variables: female literacy rate, Muslim fraction, total water availability, latitude, annual mean temperature, forest cover, and 11 cross-products of these variables. The predicted values of this regression (denoted *ddt_x*) can be interpreted as a measure of the variation in DDT usage not explained by the presence or absence of malaria itself.

The results, as we will show below match up with our prior expectation: DDT usage does not explain the likelihood that malaria disappears, but in countries where the disease is present, it is associated with lower incidence (see Section 4). However, in light of the assumptions behind the instrumenting process we are reluctant to put much weight on these particular estimates. The more important finding is that the results for income and household size are not affected by whether the DDT variable is included in the model or not, nor are they affected by any of the decisions about which variables are used to generate the DDT instrument.

2. DATA

2.1 SOURCES

Table 1 presents the variables used and their summary statistics. All data, and extensive source notes, are included in the Appendix. Observations refer to the year 2000 or the closest preceding and/or succeeding year available, except in the case of temperature, which is the annual mean over 1980-2008. The geographical units are countries or corresponding administrative units as used by the international standards according to Official Statics of Finland (OSF 2006), from which source we also obtained Population (including density and change), percentage of population in urban areas and mean household size. Note that these files were accessed in March 2006 and are not available at the source anymore, but the downloaded files can be obtained from the authors on request. Data on gross domestic product (GDP) per capita were downloaded from the World Bank.[2] Malaria prevalence was taken from World Malaria Reports (WHO 2005, 2008, 2009). Further information on malaria eradication or spontaneous disappearance was determined using Bruce-Chwatt and de Zulueta (1980) and Manguin et al. (2008). Information on vector status was compiled from the Walter Reed systematic catalogue of Culicidae,[3] the Global Infectious Diseases and Epidemiology Network (Gideon),[4] Impact malaria,[5] Becker et al. (2003) and Manguin et al. (2008). Temperature data were taken from TAT (2009). DDT country data sources are compiled in the Appendix (under the heading "Global data on the use of DDT for malaria control").

[2] http://data.worldbank.org/indicator/NY.GDP.MKTP.CD/countries/1w?display=graph.
[3] http://www.mosquitocatalog.org, accessed May 2010
[4] http://www.gideononline.com, accessed May 2007
[5] http://en.impact-malaria.com, accessed in May 2010

The variable *slum* represents the part of urban population living in inadequate housing conditions as defined by UN-Habitat (2006/7). The slum population is expressed as percentage of the urban population of the countries. Because malaria frequency was available only on the whole population level, the slum percentage was recalculated to represent the fraction of the whole population by multiplying the slum and urbanization percentages. Statistics on Muslim population are from Kettani (2010) and Miller (2009). Forest statistics were taken from the Food and Agricultural Organization (2003-2009). The variable *ddt* is binary, 1 denoting DDT was used and 0 denoting otherwise, and the variable *ddt_ignore* indicates that the country used DDT after the 1971 US ban. The annual change of population was taken from World Bank 2011.

Data on agricultural production levels by commodity type were obtained from FAOSTAT (2000). They were normalized by dividing by the rural population levels of each country. We examined several dozen possible variables, including major livestock and poultry types, and plant products including coffee, tea, cassava, rice and maize. Cassava differs from the other labour-intensive crops since its harvesting cannot be mechanized, therefore regions with high cassava production levels must have large numbers of persons working outdoors in close contact for long periods of time. We ended up discarding most of the agricultural production data since it exhibited no significant explanatory power whether averaged, formed into principal components, etc. Pig production had a significant coefficient, but there was no plausible story behind it and its exclusion or inclusion makes no difference to the rest of the model, so it was dropped as well. Cassava exhibited a significant and plausible contrast between malaria and dengue so it is retained in the model[6].

Our data set also contains observations on the percentage availability of clean water to the population (HDR-2000), and the female literacy rate (HDR-2000).

2.2 VISUAL SUMMARIES

Figure 1 shows the bifurcated nature of our data. Each panel is a histogram which shows the number of countries in each bin across the household size range. The vast majority of countries in which malaria has been eradicated have relatively small (< 4) average household size. There are only seven countries where malaria is present yet average household size is less than 4 persons (bottom panel). However, even for these countries our examination of the specific situations leads us to suspect that, within them, malaria may only be prevalent in regions with an average household size of more than four members, or in areas with corresponding housing conditions such as military camps refugee camps and camps for foreign workers or frontier settlements.

Argentina, China, Brazil and South Africa are big malarious countries with a low average household size and therefore the provincial regions were examined separately. In Argentina malaria is present in four provinces (Curto et al. 2003) and all of them have average household size higher than four (INDEC 2001). In Brazil malaria is present in nine provinces. Seven of them

[6] The data is presented as an excel spread sheet in Additional file 2.

have an average household size higher than four (Appendix). Household size is lower than four in the malarious Mato Grosso (3.78) and Rondonia (3.92). Agriculture has been expanding in Mato Grosso and since the discovery of gold there has been immigration of panminers from other malarious areas (Atanaka et al. 2007). Rondonia has experienced a similar development. Provisional housing conditions and a highly mobile population has created conditions for frontier malaria (Camargo et al. 1994). China has a low malaria prevalence, about 1.5 cases per 100 000 people. Most of them are in remote regions. There are indications that malaria in China is associated with locally high household size. Unfortunately a detailed analysis of the provinces could not be done due to the defective statistics (Additional file I, p. 15). In South Africa malaria is present in all three regions which have a household size higher than four (Gerritsen et al. 2008, Health System Trust 2000).

Malaria is also present in French Guiana, Thailand and South Korea, although the countries had an average household size lower than four (Appendix). In French Guiana malaria is prevalent only among Amerindians who have an average household size between 5 and 7 (Hustache et al. 2007, Legrand et al. 2008). Thailand received almost 1.3 million immigrants from neighbouring, highly malarious countries in 2004 (WHO 2008). Malaria in Thailand is consequently found in regions close to the borders or in regions with foreign workers (Anderson et al. 2011, WHO 2008). Malaria re-emerged in South Korea in the 1990's. It spread first among military personnel in military camps and then among civilians primarily in areas adjacent to the Demilitarized Zone (Huldén and Huldén 2008, Park et al. 2009).

On its own, the bifurcation shown in Figure 1 is not conclusive since it might be due to the influence of a more primary variable, such as income or education. What we will show in the next section is that household size has a unique effect, independent of income and other socioeconomic influences. We will make use of the apparent truncation effect at 4 persons visible in the lower panel of Figure 1, by representing household size as a continuous variable and also as a binary large/small indicator, with the threshold between large and small varying from 3 up to 7 persons.

Figures 2a and 2b shows the same histogram pair for, respectively, standardized income, absolute latitude, female literacy, urbanization, mean temperature and duration of DDT usage. While the observations cluster somewhat differently, the degree to which the samples differ is much less—in other words the distributions overlap more.

Figure 2b shows the distributions for two covariates that have been the subject of particularly contentious discussions. The histograms on the left show that annual mean temperature does not meaningfully separate the samples, since the spans are nearly identical, though there is a modal concentration of continuing malaria presence in relatively hot countries. However the multivariate analysis will show that this is not due to temperature. Looking at the DDT histograms, there is a large modal concentration of countries that did not use DDT among the group in which malaria has been eradicated. Also, the countries where DDT was used for the longest time are among the nations where it is still present, which is an indication of the endogeneity problem noted above.

Our data set is cross-sectional, but we also examined some time series data for 23 countries, as shown in Figure 3. The sample includes 11 countries in which malaria spontaneously disappeared and 12 where an eradication campaign was carried out. Spontaneous disappearance of malaria mainly occurs when household size falls below 4 persons, the exception being Japan. In the countries where eradication campaigns were undertaken, only 3 of 11 reached success with household sizes above 4 persons. Albania is interesting in this respect because it is a predominantly Muslim country. We will report on the significance of the Muslim fraction in the next section. Our conjecture is that in some regions, Muslim practise involves segregated sleeping quarters, thereby reducing the effective household size.

3. Methods of Analysis

3.1 Probit Regression

We defined a binary eradication indicator variable *mal_erad* which takes the value 0 if malaria is still present and 1 if malaria was historically present but has disappeared. We fitted a multivariate probit model (see, e.g., Davidson and MacKinnon 2004) of the form:

$$P(mal\_erad) = f(\mathbf{Xb}) + \mathbf{e} \quad (1)$$

where $P(mal\_erad)$ is the probability of malaria eradication; f is the cumulative normal curve; $\mathbf{X}$ is a matrix of i explanatory variables x_{ij}, i=1,…,k (including a constant) for j = 1,…, 188 countries, $\mathbf{b}$ is a k-vector of coefficients; and $\mathbf{e}$ is a vector of independent and identically distributed error terms. Country subscripts will be omitted in the subsequent discussion except where needed for clarity. In probit estimation, the function P is assumed to be the Gaussian cumulative normal curve. Estimation of (1) yields coefficients that can be used to compute marginal probabilities:

$$\beta_i = \frac{\partial P}{\partial x_i}, \quad (2)$$

and their associated standard errors. This shows the change in the probability of (in this case) malaria eradication as a result of a change in the value of the explanatory variable. Equation (2) is customarily evaluated at the sample means of the explanatory variables. The standard errors of the coefficients in $\mathbf{b}$ are not the same as the standard errors for the marginal probabilities given by (2), and it is possible for one to be significant but not the other.

3.2 Tobit Regression

Observations on malaria frequency (*mal_freq*) are truncated at zero, even though the explanatory factors may continue into a range where a linear model would predict negative values. Thus estimation of a simple linear model

$$mal\_freq = \mathbf{Zg} + \mathbf{z}\,, \qquad (3)$$

where **Z** is the matrix of explanatory variables, **g** is the coefficient vector and **z** is the vector of error terms, would yield biased slope coefficients and variances if the censoring of the data were not taken into account. The tobit model (see. Davidson and MacKinnon 2004) involves defining a latent variable, denoted m^0, which is only observed when *mal_freq* is positive, and is zero otherwise, yielding the conditional model

$$m^0 = \begin{cases} \mathbf{Zg} + \mathbf{z} & if \;\; m^0 > 0 \\ 0 & otherwise \end{cases} \qquad (4)$$

A loglikelihood function can be derived for this model. In effect it combines the linear regression in (3) with a probit term for the censored observations. This yields unbiased estimates of the slope coefficients **g**.

In both the probit and tobit regressions the errors **z** are adjusted for heteroskedasticity using White's method.

4. Results

4.1 Probability of malaria eradication

Model (1) was estimated using explanatory variables from among those listed in Table 1. The main variable of interest is household size. It was examined as a continuous variable (*hhsize*) and also as a group of dummy variables denoted *hh_under3* if household size is less than 3, and so on for 4, 5 and 6. Table 2 shows the results of three estimations: omitting household size, including it as a continuous variable, and including the dummy variable for a threshold of four persons. In the latter case the results are shown as the linear coefficients (see Equation 1) and, in the final column as the marginal probability terms (Equation 2).

In Table 2 a positive coefficient implies an increased probability of malaria eradication. Standardized income is positive and significant across all specifications. Population density is, somewhat surprisingly, positive and significant, while slum fraction and population growth are negative and significant in two of three specifications. Temperature and latitude are insignificant in all specifications. The DDT instrument is negative and insignificant in each case. Female literacy and cassava production (an indicator of extensive outside labour) are insignificant

Comparing the third and fourth columns, when household size is included as a continuous variable the coefficient is small, negative and insignificant, but when it is included as an indicator variable at the 4-person threshold, the size of the income coefficient drops, the household size effect becomes not only positive but also the largest and most significant (largest *t*-statistic) in the model. This threshold is the only integer value where the household size effect is significant. Figure 4 shows the marginal probability estimates for the four household size dummy variables. When the average household size drops below four persons the probability of malaria eradication increases by 70%, ceteris paribus, an effect a little smaller than that of a one standard-deviation increase in average income. (Note that the increase in probability is additive, not multiplicative, that is, the effect is $P+0.7$ not $P \times 1.7$.)

Looking at Figure 1, we see that Malaria has been successfully eradicated from 13 countries with an average household size greater than four members. They are of special interest because all except two (Saint Vincent & Grenadines 4.3, British Virgin Islands 4.4) are Muslim countries with an average household size of 5.75 in 2000 (Table 3). Although the Muslim share of the population is insignificant in relation to the overall malaria index on a worldwide basis, this factor is still important regionally. Households in Muslim countries are characterized by a gender-separating organization which in varying degree divides the household in smaller units depending on how strictly the country is applying the practice of gender segregation (Esposito 2009). Hence these are countries that may have relatively large household on average, but effective household sizes below four persons as regards sleeping arrangements. Table 2 shows that when household size is modeled as a 4-person threshold, the Muslim fraction coefficient becomes positive and significant as a predictor of the probability of malaria eradication.

4.2 Factors affecting malaria frequency

We now repeat the same type of analysis except we use malaria frequency (*mal_freq*) as the dependent variable and the estimation method is the tobit model. Table 4 shows the results from using all the household size variations. Notice that in comparison to the other specifications, inclusion of household as a dummy variable at the 4-person threshold yields the largest (and only significant) household size effect, the size of the income effect drops by 30-33% compared to the other cases, and the household size effect obtains the largest *t*-statistic. Across all other specifications, a one standard deviation increase in national income is associated with a significant drop in malaria frequency of about 12,000 cases (per hundred thousand population), but when household size enters as a 4-person threshold, the income effect falls to 8,300. Population size and latitude have significant effects across all specifications, and female literacy and the Muslim fraction are significant in four of five cases, though the effects are small. Annual mean temperature is insignificant across all specifications, and the coefficient is always negative, indicating higher temperature implies (if anything) fewer malaria cases. Hence we find no support for the claim that a warming trend would increase malaria prevalence. Water availability, urbanization, forest cover and slum prevalence are not significant factors.

The *ddt_x* variable, denoting variations in the usage of DDT not predicted by the presence of malaria, is negative in all cases, as expected, and significant in the *hh_under4* case. The units are somewhat obscure, but the size of the coefficient can be taken to imply that an additional year of DDT is associated with several hundred fewer cases of malaria, an effect much smaller than increases in income or reduction in household size below the 4-person threshold. This may or may not be a direct effect of DDT itself, instead it may reflect the willingness of a government to engage in aggressive malaria control.

Figure 5 shows a comparison of the income and household size effects. The difference at the 4-person threshold is quite clear. The household size effect becomes large and significant and the income effect falls by about one-third in magnitude.

4.3 Comparison to dengue

The mechanism behind the empirically derived threshold value of a household size of four members should be explained. An average household size below four members implies that the human population itself is on a decreasing path. This could indicate that the *Plasmodium* is somehow dependent on the surplus of humans in a household, principally represented by the presence of 3 or more children. While a mosquito is the local spreader of malaria, a human is practically the only long distance spreader. The long distance dispersal of the *Plasmodium* is maintained by continuous social contacts between human households over various distances. In communities with relatively few children these contacts decrease below a critical value at which the *Plasmodium* faces more extinctions than replacements via human contacts. A mathematical model is still to be developed for an exact description of the process.

As mentioned above, dengue fever has a different transmission mechanism than malaria. It is an emerging viral disease of major public health significance with a wide geographic distribution (Guha-Sapir and Schimmer 2005). The main dengue vector is *Aedes aegypti*. The female feeds predominantly during day in shaded places and only occasionally during the night in lit rooms (Becker et al. 2003). Consequently the principal mosquito vectors of dengue are day-biting and closely associated with humans (Morrison et al. 2008). Humans usually provide suitable water-containers (e.g. empty plastic bottles, abandoned tires, temporary ditches) for the development of the larvae and the blood meal for the females. Dengue *vires* infection cannot be prevented with any vaccine and there is no specific treatment for infection (Murrell et al. 2011).

Since the transmission of dengue is connected with human activity during the day, as opposed to night when malaria is transmitted to sleeping people, dengue transmission provides a good test of whether the household size effects on malaria are realistic or not. While we did not have data on dengue eradication we were able to obtain observations on dengue frequency for 121 of our 188 countries. We re-estimated the tobit model with dengue as the dependent variable and the results are in the last column of Table 4. There are a number of noteworthy differences. First, household size and income effects disappear, as do population growth, the Muslim fraction and DDT usage. Instead cassava production emerges as significant, which adds plausibility to the overall findings. We also examined other commodities, including both animal and crop variables, but they had no explanatory power.

The main weakness of this test is that the explanatory variable and the sample size both change simultaneously. We ran the malaria frequency regression on the 121-country subsample, and while the results are similar to those on the full sample the effects are generally smaller. Income falls to marginal significance and *hh_under4* becomes insignificant. Latitude and female literacy become insignificant while *slum* becomes marginally significant. In other words, the subsample has some different characteristics compared to the entire sample. Nevertheless, the signs and magnitudes resemble those on the whole sample, whereas a comparison of coefficients from the dengue model and the malaria model on either the partial or full sample show no similarity at all.

5. Discussion and Conclusions

Humans have historically been the carriers of malaria infections to new regions (Beklemishev 1959). The process continues today, and in the malaria-free industrialized countries, long range dispersal of the disease is equivalent to the rate of annual imported cases. Although a suitable local *Anopheles* species is often present, repopulation of the parasite is not successful and malaria does not re-establish itself. We find that this is because of low household size. In countries with a high household size the situation is different. There the malaria influx with population movements persistently affects national malaria eradication programs (Tatem and Smith 2010).

Endemic malaria required the presence of a suitable mosquito vector, but its presence or absence had no impact on the long term trend. Instead it determines the high frequency trend, in other words the annual variations and epidemics. There can be considerable annual variations in the vector populations and they are usually dependent on meteorological conditions. When the *Anopheles* population is big, the number of infected households increases. Mosquito control is essential for breaking of epidemics and limiting the number of local malaria cases. It will, however, not lead to eradication, as is indicated by our results on DDT usage. Despite more than a hundred years of effort, vector eradication has only been achieved twice, in the Maldives and in Palestine (Appendix). Still, it can be used for shortening the time required for eradication. This was shown by Lysenko et al. (1999) and Solokova and Snow (2002), who analysed the decline of malaria in the USSR, where DDT was introduced in 1949 for vector control. A comparison between malaria eradication in the United Kingdom and the Netherlands shows that an eradication program with effective vector control and medication can make the final decline steeper and the eradication process faster, if the household size is low enough (Figure 6). In the United Kingdom the spontaneous decline of malaria was slow with a long "tail" of sporadic cases. The eradication programs in the Netherlands made the malaria trend drop very fast during the final phase.

Today bed nets are widely used as a tool in the fight against malaria. It is generally acknowledged that bed nets have the potential to reduce malaria incidence. The mean index of bed nets per person in 35 African countries is 0.21. (WHO 2009). No country has so far got rid of malaria with bed nets. In Aneityum in Vanuatu (household size 5.6) a high provision of individual bed nets (0.94 nets per person) has, in combination with effective drug distribution and surveillance, resulted in a disappearance of malaria since 1996 onwards (Kaneko et al. 2000, Kaneko 2010). The use of individual bed nets emulates a house with several bedrooms making it more difficult for an infective vector to transmit the parasite to all the household members.

The first global strategy for the eradication of malaria was adopted in 1955. It concentrated on an effective use of DDT, which aimed to stop transmission by destroying the vector. It was largely successful in controlling epidemics and lowering the number of malaria cases (Harrison 1978). A new attempt in eradicating the disease started in 2007. How the goal can be achieved is under debate (Feachem and Sabot 2008). Our results indicate, however, that household size ultimately determines the success of malaria eradication on country level. Therefore household size and variables that affect it, should be included in the eradication plans.

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TABLES

Variable	Description	Mean	Std. Dev.	Min	Max
mal_erad	Malaria eradicated (=1) or not (=0)	0.436	0.497	0.000	1.000
mal_freq	Malaria frequency (cases per hundred thousand)	2722.815	6689.160	0.000	48790.000
dengue	Dengue frequency (cases per hundred thousand)	78.357	410.090	0.000	4006.150
hhsize	Mean household size	4.430	1.454	2.100	8.700
hh_under3	HH size under 3 persons	0.181	0.386	0.000	1.000
hh_under4	HH size under 4 persons	0.404	0.492	0.000	1.000
hh_under5	HH size under 5 persons	0.638	0.482	0.000	1.000
hh_under6	HH size under 6 persons	0.835	0.372	0.000	1.000
std_inc	Standardized income	-0.102	0.867	-0.644	3.191
popden	Population density (persons/km^2)	310.578	1384.409	2.300	16300.400
chgpop	Average annual Population change during 1997-2001	1.410	1.226	-1.728	5.875
urban	% living in urban area	54.381	24.296	8.600	100.000
muslim	% Muslim	25.979	37.281	0.010	100.000
water_tot	% with access to clean water	79.698	18.329	22.000	100.000
lat	Latitude (degrees)	24.473	16.147	0.250	61.250
ann_temp	Mean annual temperature, 1980-2008	18.141	6.808	-0.838	28.086
forest	% of land covered with forest	29.860	21.613	0.000	94.700
slum	% living in slums	11.646	14.038	0.000	53.030
female_lit	Female literacy rate	77.670	24.840	3.000	100.000
cassava	Cassava production (1000 tonnes p.a.)	0.031	0.105	0.000	0.969
ddt	DDT used (=1) after 1940 or not (=1)	0.777	0.418	0.000	1.000
ddt_ignore	DDT used after 1971 (=1) or not (=0)	0.383	0.487	0.000	1.000
ddt_x	DDT Instrument (see Section 1.2)	6.362	5.932	-7.743	28.900

Table 1: Variable names and summary statistics. *N* = 188 in all categories.

Variable	prob_nohh	prob_hh	prob_hh4	dF/dX (hh4)
std_inc	**2.975**	**2.710**	**2.266**	**0.904**
	(3.32)	(3.61)	(3.52)	(3.52)
popden	**0.002**	**0.002**	**0.003**	**0.001**
	(1.96)	(1.96)	(2.62)	(2.62)
chgpop	-0.507	**-0.550**	**-0.533**	**-0.212**
	(-1.79)	(-2.20)	(-2.31)	(2.31)
urban	0.017	0.016	**0.022**	**0.009**
	(1.55)	(1.62)	(1.97)	(1.97)
muslim	0.002	0.009	**0.018**	**0.007**
	(0.35)	(1.16)	(2.56)	(2.56)
water_tot	0.022	0.020	0.025	0.010
	(1.56)	(1.32)	(1.53)	(1.53)
lat	0.033	0.026	-0.005	-0.002
	(1.17)	(0.93)	(-0.17)	(0.17)
ann_temp	0.072	0.072	0.034	0.014
	(1.50)	(1.50)	(0.72)	(0.72)
forest	-0.008	-0.009	-0.007	-0.003
	(-0.77)	(-0.86)	(-0.59)	(0.59)
slum	**-0.045**	-0.037	**-0.047**	**-0.019**
	(-2.41)	(-1.80)	(-2.34)	(2.34)
female_lit	0.019	0.022	0.008	0.003
	(1.09)	(1.25)	(0.51)	(0.51)
ddt_x	-0.051	-0.040	-0.077	-0.030
	(-1.01)	(-0.75)	(-1.45)	(1.45)
cassava	0.170	0.337	-0.525	-0.209
	(0.11)	(0.22)	(-0.29)	(0.29)
hhsize		-0.334		
		(-1.14)		
hh_under4			**2.076**	**0.692**
			(4.14)	(4.14)
_cons	-4.606	-3.541	-4.156	
	(-1.60)	(-1.12)	(-1.45)	
N	188	188	188	188
Pseudo-R^2	0.718	0.724	0.774	0.774

Table 2. Results from probit regression. Column 1: variable names. Column 2: model without household size. Column 3: model with household size as a continuous variable. Column 4: household size included as a dummy variable at the 4-person threshold, linear slope coefficients. Column 5: same, but showing the marginal probabilities. All models estimated with White's correction for heteroskedasticity. Bold-face denotes significant at 5%.

	Muslim %	Household size		Muslim %	Household size
Albania	79.9	4.2	Libya	97.0	6.3
Bahrain	81.0	5.9	Maldives	100	7.1
Brunei	67.0	6.0	Palestine	97.5	7.2
Jordan	95.0	5.3	Tunisia	98.0	4.7
Kosovo	90.0	6.0	United Arab Emirates	76.0	6.2
Lebanon	60.0	4.3			

Table 3: Countries with mean household size greater than 4, and malaria eradicated.

Variable	no_hh	hh3	hh4	hh5	hh6	den_hh4
std_inc	**-12303.5**	**-12035.6**	**-8301.2**	**-11820.3**	**-11892.7**	-57.381
	-3.08	-2.94	-2.25	-3.06	-2.94	(-0.41)
popden	-3.789	-3.648	-3.665	-3.872	-4.036	0.003
	-0.81	-0.78	-0.80	-0.85	-0.86	(0.06)
chgpop	**2222.517**	**2223.358**	**1937.030**	**2105.550**	**2168.107**	-66.314
	2.63	2.63	2.33	2.52	2.55	(-1.24)
urban	-44.045	-44.768	-35.421	-35.919	-48.277	2.461
	-0.91	-0.93	-0.72	-0.75	-0.99	(0.65)
muslim	**-46.768**	**-47.675**	**-69.791**	**-54.135**	-41.666	0.540
	-2.03	-2.05	-2.89	-2.34	-1.67	(0.17)
water_tot	75.304	75.027	77.013	86.760	72.812	8.405
	1.59	1.59	1.64	1.83	1.53	(1.74)
lat	**-237.156**	**-231.153**	**-199.022**	**-235.727**	**-234.621**	0.314
	-2.61	-2.48	-2.17	-2.62	-2.58	(0.03)
ann_temp	-112.067	-113.509	-87.098	-114.053	-107.632	17.185
	-0.68	-0.69	-0.53	-0.70	-0.65	(0.91)
forest	-38.858	-37.118	-44.847	-38.893	-36.782	3.127
	-1.07	-1.01	-1.24	-1.08	-1.01	(0.96)
slum	21.033	21.566	-8.955	13.174	26.502	-10.261
	0.34	0.35	-0.14	0.22	0.42	(-1.62)
female_lit	**-93.593**	**-94.585**	**-107.583**	-83.269	**-96.141**	-3.532
	-2.07	-2.09	-2.38	-1.85	-2.11	(-0.66)
cassava	5661.184	5590.824	5931.092	3423.092	6448.839	**1144.813**
	0.91	0.90	0.96	0.54	1.01	(1.96)
ddt_x	-244.709	-249.162	**-322.649**	-228.611	-237.286	14.951
	-1.70	-1.72	-2.23	-1.60	-1.64	(0.75)
hh_under3		-1111.402				
		-0.28				
hh_under4			**-6871.476**			125.094
			-2.98			(0.68)
hh_under5				-2630.059		
				-1.62		
hh_under6					1060.825	
					0.55	
_cons	6302.198	6503.120	11146.089	6473.772	5801.362	-893.678
	0.82	0.84	1.46	0.85	0.75	-1.24
N	188	188	188	188	188	121
ll	-1105.656	-1105.616	-1101.044	-1104.364	-1105.506	-807.991

Table 4: Tobit regression results. Final column shows results using dengue frequency as the dependent variable. _se denotes an extra scaling parameter estimated as part of the tobit model.

FIGURES

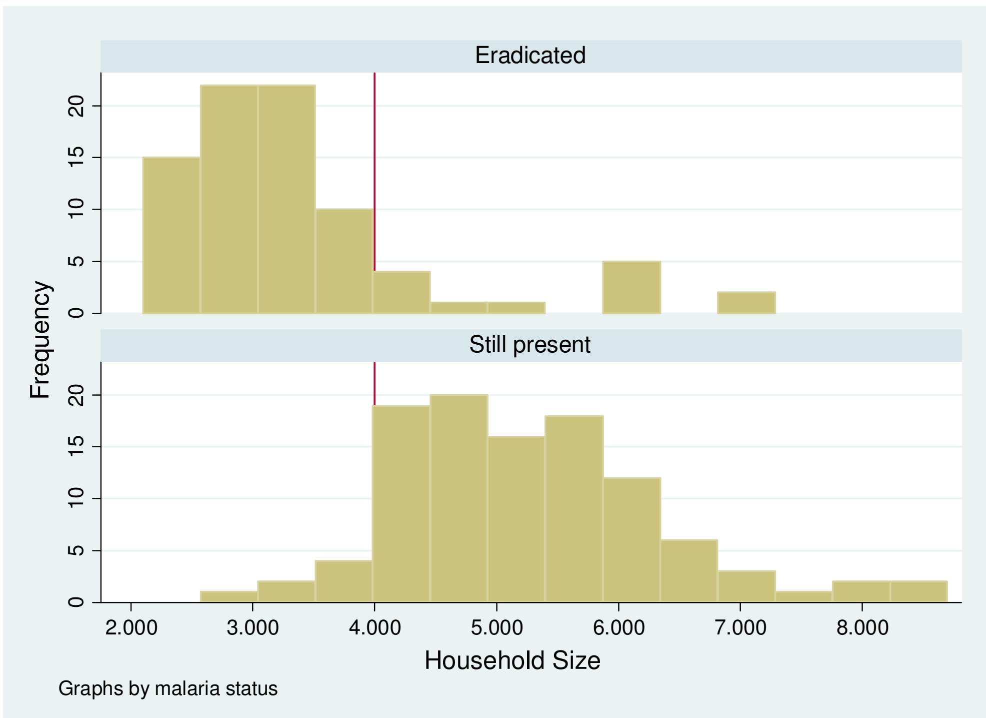

Figure 1. Histograms of malaria frequency (number of countries) versus household . Top: countries in which malaria was eradicated as of 2000. Bottom: countries where malaria is still present.

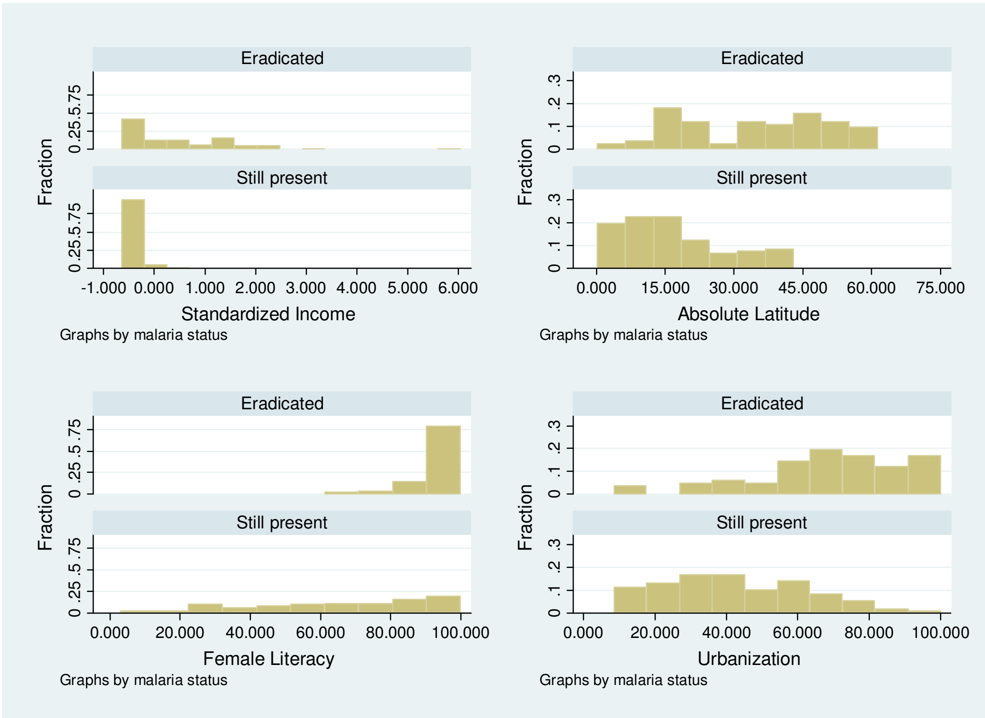

Figure 2a. As for Figure 1, but for 4 other covariates. Note the vertical axis is sample fraction; scale differs between columns to aid readability.

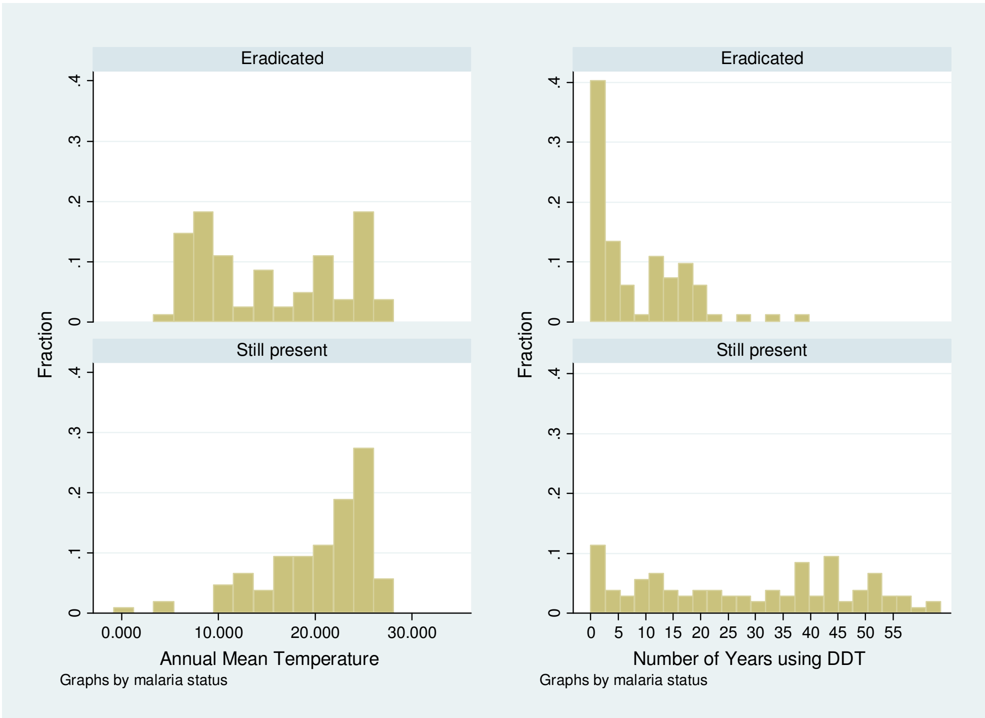

Figure 2b. As for Figure 2a, but for annual mean temperature and DDT usage.

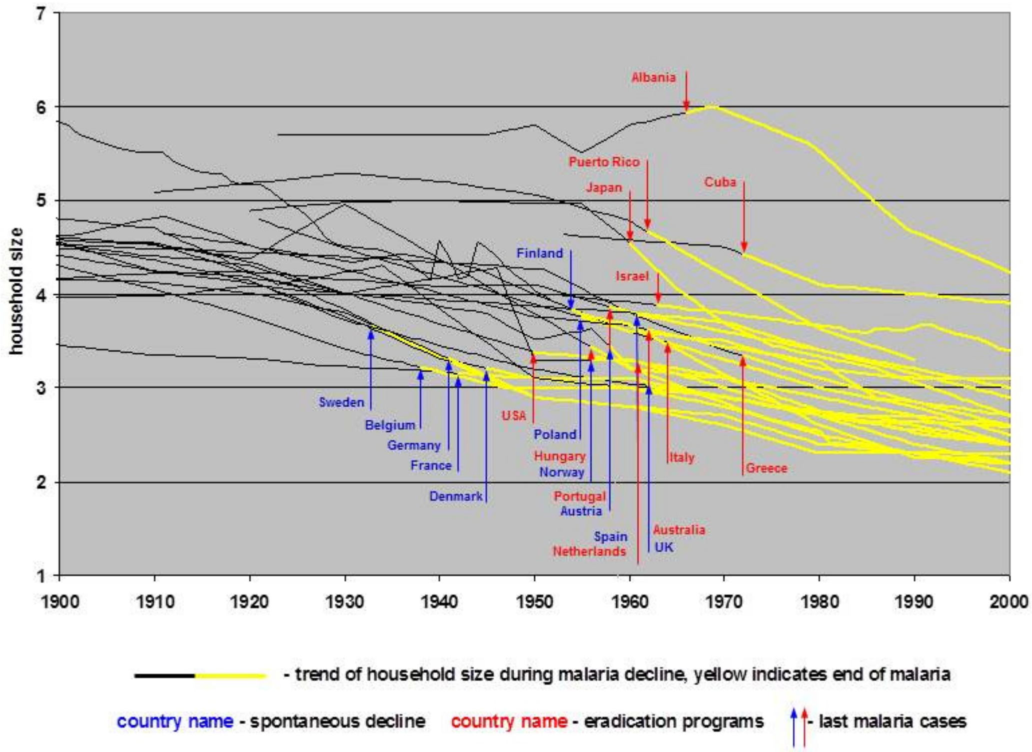

Figure 3. Trends of household size in 23 countries, showing end of malaria in 12 countries that had a malaria eradication program (red arrow) and 11 countries without eradication program (blue arrow).

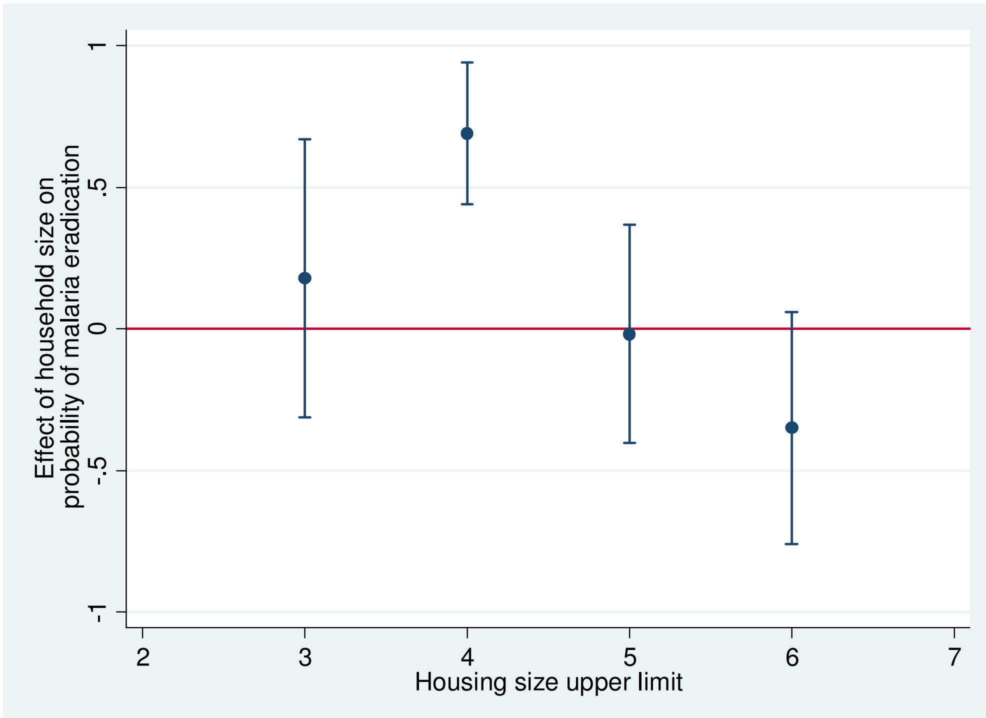

Figure 4. Change in probability of malaria eradication when household size drops below indicated threshold

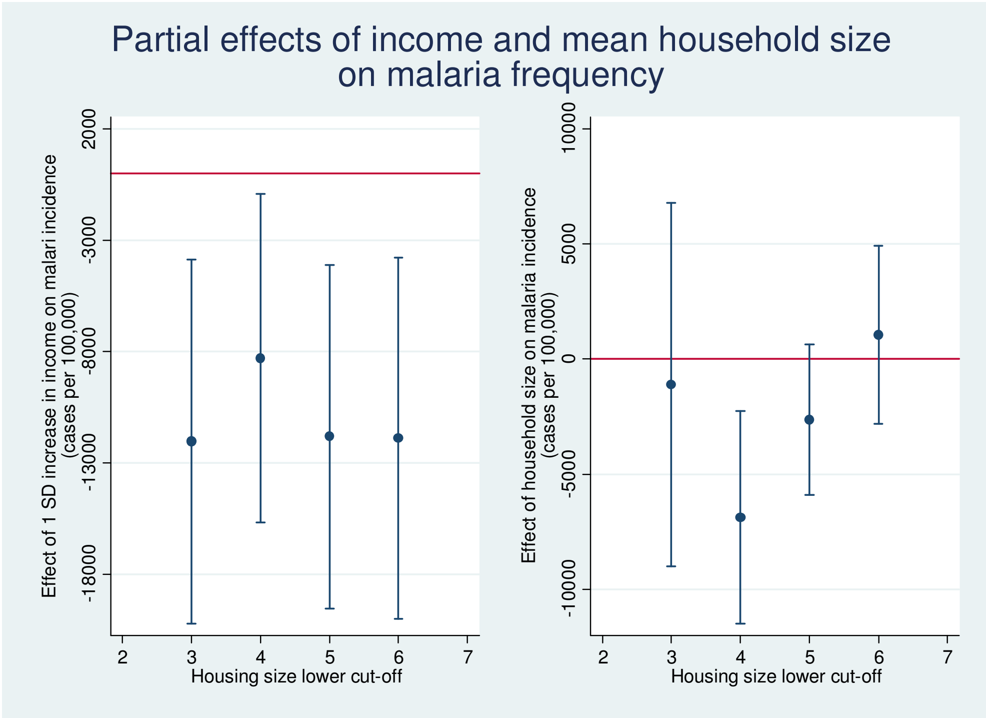

Figure 5. Left panel: partial effects of income on malaria frequency with household size represented as a dummy variable at the indicated thresholds. Right panel, same but measuring effect of household size falling below the indicated threshold.

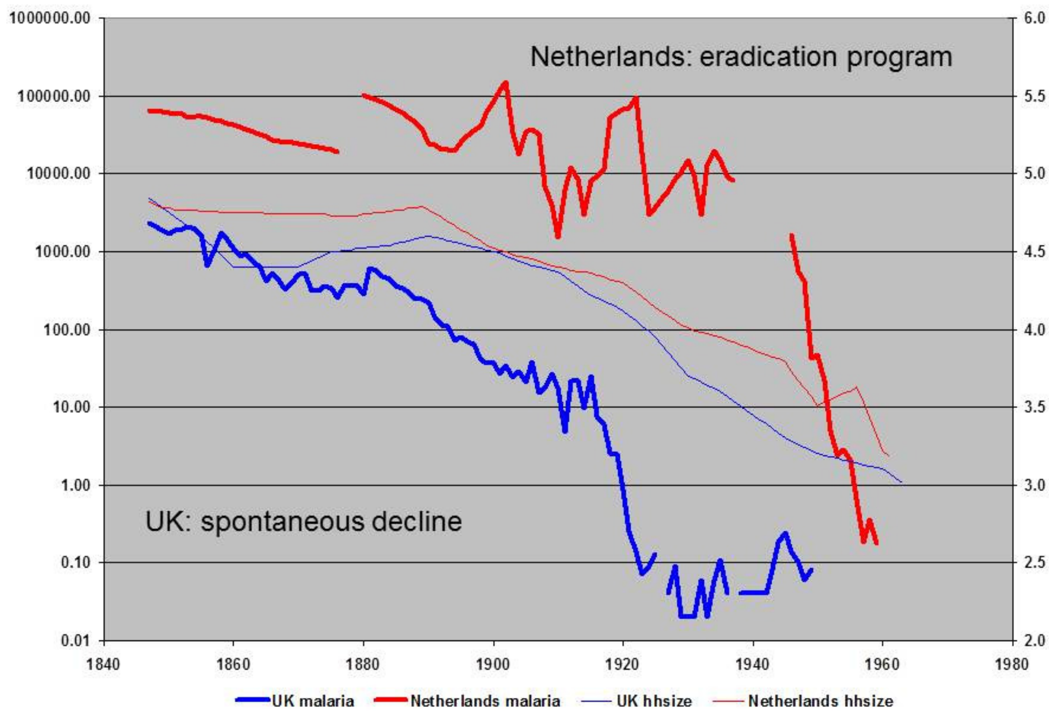

Figure 6. Graph showing the difference between countries depending on if eradication programs were used or not used. Eradication programs leads to abrupt decline of malaria when the household size approaches four members Malaria index to the left is presented as cases per 1 million people (note logarithmic scale).

Appendix

A1. Global data on malaria and analyzed factors

The data used for the analysis are presented in two tables and country-based comments. The separately commented countries are marked with * in the tables. Table 1 presents vector status, malaria status, last case of malaria, household size and malaria prevalence (cases / 100000 people) in 2000. Table 2 presents population density, GDP per capita, urbanization level, the percentage of the population living in slums, the percentage of Muslims of the population, female literacy and forest coverage in percentage of country area. The main sources were critically reviewed and complementary additions are presented in the comments.

The collected data is from the year 2000 or estimated from the closest preceding and/or succeeding years. The geographical units are countries or corresponding administrative units as used by the international standards according to the Official Statistics of Finland (OSF 2006). Most data on gross domestic product (GDP) per capita in 2000 was downloaded from the World Bank (World Bank 2010). GDP for some of the lacking countries or deviating years was added from CIA World Factbooks. These are indicated in the table with C and/or a year in brackets. Population data, density, percentage of urban population and household size are principally from Statistics Finland (OSF 2006). Historical data on household size for selected countries were compiled from Rothenbacher (2002) and from certain other countrywise sources (Rothenbacher 2002, King and Mai 2008, ABS 2010, Luzón 1988, State of Israel 2010, Ministry of Internal Affairs and Communications of Japan 2010. 10, Rivera-Batiz and Santiago1996, United States Census Bureau 2010). Note: The Statistics Finland files were accessed in March 2006 and are not available any more on internet. Copies of them can be provided on request from the author.

Malaria prevalence has been interpreted using World Malaria Reports (Roll Back Malaria 2005, WHO 2008, WHO 2009). Further information on malaria eradication or spontaneous disappearance is determined mainly according to Bruce-Chwatt & de Zulueta (1980) and Manguin et al. (2008). Information on vector status has been compiled from Walter Reed systematic catalogue of Culicidae, Gideon database, Impact malaria, Becker et al. (2003) and Manguin et al. (2008).

The data on dengue cases are taken from Regional WHO offices (WHO-Dengue 2011) and updates from Weekly Epidemiological Record (WHO-WER 2011). The final dengue index is calculated as the annual mean number of cases per 100000 people for the years 1990-2010. This time range is used to catch at least some of the peaks for each country. Dengue peaks occur usually in 3-10 year intervals.

Slum represents the part of the urban population living in inadequate housing conditions as defined by UN-Habitat (2006). The slum population is expressed as % of urban population of the countries. Because malaria frequency was available only on the national population level, the slum percentage was recalculated according to the country level by multiplying the slum and urbanization percentages (139 countries). Numbers in brackets are calculated according to the number of homeless people as percentage of the whole population from 17 industrialized countries UN-Habitat 2004). Statistics on Muslim population are from Kettani (2010) and Miller (2009). Statistics on female literacy are from UNPD Human development reports (2004). In 22 cases the female literacy rate was unavailable so the population literacy rate was used instead (value marked with *). In 6 cases neither the female nor the population literacy rates were available. Forest statistics was taken from FAO (2003, 2005, 2007, 2009).

Table A1. Vector status, malaria elimination, eradication, household size and malaria cases

Country	Vector Status	Malaria elimination status	Eradication year/last case	House-hold size	Malaria cases / 100 000
Afghanistan *	+ vectors	Endemic		6.0	950.00
Albania	+ vectors	extinct	1966	4.2	0.00
Algeria	+ vectors	endemic		6.2	0.21
American Samoa	no vectors	never endemic		6.1	0.00
Andorra	no vectors	never endemic		2.8	0.00
Angola	+ vectors	endemic		4.7	13210.00
Anguilla	no vectors	never endemic		3.1	0.00
Antigua & Barbuda *	+ vectors	extinct	1952	3.1	0.00
Argentina *	+ vectors	endemic		3.4	1.19
Armenia *	+ vectors	endemic	(~1963) +1994	4.1	1.82
Aruba	no vectors	never endemic		5.0	0.00
Australia	+ vectors	extinct	1962	2.7	0.00
Austria	+ vectors	extinct – spontaneous	1946	2.4	0.00
Azerbaijan *	+ vectors	endemic	(~1967) +1995	4.7	18.70
Bahamas *	+ vectors	extinct	~1962	3.5	0.00
Bahrain *	+ vectors	extinct	1979	5.9	0.00
Bangladesh	+ vectors	endemic		5.0	39.90
Barbados *	Imported	never endemic, occasional		3.4	0.00
Belarus *	+ vectors	extinct	1956	2.6	0.00

Belgium *	+ vectors	extinct – spontaneous	1938	2.4	0.00
Belize	+ vectors	endemic		4.6	620.00
Benin	+ vectors	endemic		5.6	11370.00
Bermuda	no vectors	never endemic		2.3	0.00
Bhutan	+ vectors	endemic		5.5	290.00
Bolivia	+ vectors	endemic		4.2	380.00
Bosnia & Herzegovina	+ vectors	extinct	1959	3.6	0.00
Botswana	+ vectors	endemic		4.1	4140.00
Brazil *	+ vectors	endemic		3.8	360.00
Brunei *	+ vectors	extinct	1970	6.0	0.00
Bulgaria	+ vectors	extinct	1960	2.7	0.00
Burkina Faso	+ vectors	endemic		6.0	8680.00
Burundi	+ vectors	endemic		5.4	48790.00
Cambodia	+ vectors	endemic		5.2	470.00
Cameroon	+ vectors	endemic		5.5	4600.00
Canada *	+ vectors	extinct	1910	2.7	0.00
Cape Verde	+ vectors	endemic		4.6	31.70
Cayman Islands *	+ vectors	extinct	1950’s	2.6	0.00
Central Africa	+ vectors	endemic		5.5	2410.00
Chad	+ vectors	endemic		5.4	4700.00
Chile *	+ vectors	extinct	1945	3.8	0.00
China *	+ vectors	endemic		3.6	1.47
Christmas Island	no vectors	never endemic		2.9	0.00
Cocos (Keeling) Island	no vectors	never endemic		4.0	0.00
Colombia	+ vectors	endemic		4.9	260.00
Comoros	+ vectors	endemic		6.3	1360.00

Congo Republic (Brazzaville)	+ vectors	endemic		7.2	530.00
Congo Democratic Republic (Kinshasa)	+ vectors	endemic		6.1	1990.00
Cook Islands	no vectors	never endemic		4.1	0.00
Costa Rica	+ vectors	endemic		4.1	47.80
Cote d'Ivoire (Ivory Coast)	+ vectors	endemic		8.1	9430.00
Croatia	+ vectors	extinct	1952	3.1	0.00
Cuba *	+ vectors	extinct	1967	3.9	0.00
Cyprus*	+ vectors	extinct	1953	3.1	0.00
Czech Republic	+ vectors	extinct – spontaneous	1958	2.7	0.00
Denmark *	+ vectors	extinct – spontaneous	1945	2.2	0.00
Djibouti *	+ vectors	endemic	(1910) +1973	5.3	700.00
Dominica *	+ vectors	extinct	1959	3.1	0.00
Dominican Republic *	+ vectors	endemic		4.5	13.90
Ecuador	+ vectors	endemic		4.2	790.00
Egypt *	+ vectors	endemic		4.7	0.10
El Salvador	+ vectors	endemic		4.2	12.03
Equatorial Guinea	+ vectors	endemic		8.2	3130.00
Eritrea	+ vectors	endemic		4.8	3210.00
Estonia *	+ vectors	extinct – spontaneous	1952	2.4	0.00
Ethiopia	+ vectors	endemic		5.2	580.00
Faeroe Islands	no vectors	never endemic		2.8	0.00
Falkland Islands	no vectors	never endemic		2.7	0.00
Fiji	no vectors	never endemic		4.7	0.00
Finland *	+ vectors	extinct – spontaneous	1954	2.1	0.00

France *	+ vectors	extinct – spontaneous	1943 / 1973	2.4	0.00
French Guiana *	+ vectors	endemic		3.4	2260.00
French Polynesia	no vectors	never endemic		4.0	0.00
Gabon	+ vectors	endemic		6.9	6680.00
Gambia	+ vectors	endemic		8.6	10050.00
Georgia *	+ vectors	endemic	(~1970) +1996	4.0	5.17
Germany	+ vectors	extinct – spontaneous	1941	2.2	0.00
Ghana	+ vectors	endemic		4.3	17100.00
Gibraltar *	+ vectors	extinct – spontaneous	19th century	3.7	0.00
Greece	+ vectors	extinct	1972	2.6	0.00
Greenland	no vectors	never endemic		4.0	0.00
Grenada *	+ vectors	extinct	1959	3.3	0.00
Guadeloupe *	+ vectors	extinct	1960’s	3.4	0.00
Guam *	imported	never endemic		3.7	0.00
Guatemala	+ vectors	endemic		4.4	470.00
Guinea	+ vectors	endemic		6.6	10950.00
Guinea-Bissau	+ vectors	endemic		5.7	18020.00
Guyana	+ vectors	endemic		4.2	3170.00
Haiti	+ vectors	endemic		4.7	210.00
Honduras	+ vectors	endemic		4.6	540.00
Hong Kong *	+ vectors	extinct	1988	3.2	0.00
Hungary	+ vectors	extinct	1956	2.6	0.00
Iceland	no vectors	never endemic		2.3	0.00
India	+ vectors	endemic		5.3	200.00
Indonesia	+ vectors	endemic		4.5	120.00
Iran	+ vectors	endemic		4.6	29.80

Iraq	+ vectors	endemic		6.4	7.42
Ireland *	+ vectors	extinct – spontaneous	1900's	3.0	0.00
Israel *	+ vectors	extinct	1963	3.4	0.00
Italy *	+ vectors	extinct	1964 / 1957	2.5	0.00
Jamaica *	+ vectors	extinct	1958	3.5	0.00
Japan *	+ vectors	extinct	1961	2.7	0.00
Jordan *	+ vectors	extinct	1997	5.3	0.00
Kazakhstan *	+ vectors	extinct	1967	3.6	0.00
Kenya	+ vectors	endemic		4.4	240.00
Kiribati	no vectors	never endemic		6.7	0.00
Korea North *	+ vectors	endemic	(1979) +?1995	4.0	890.90
Korea South *	+ vectors	endemic	(1979) +1993	2.8	8.81
Kosovo	+ vectors	extinct	1959	6.0	0.00
Kuwait *	?occasional	never endemic		4.8	0.00
Kyrgyzstan *	+ vectors	endemic	(~1960) +1996	4.5	0.14
Laos	+ vectors	endemic		6.2	760.00
Latvia *	+ vectors	extinct – spontaneous	1953	2.7	0.00
Lebanon *	+ vectors	extinct	1963	4.3	0.00
Lesotho *	no vectors	never endemic		4.9	0.00
Liberia	+ vectors	endemic		5.7	30150.00
Libya	+ vectors	extinct	2000	6.3	0.00
Liechtenstein *	+ vectors	extinct – spontaneous	1910	2.7	0.00
Lithuania *	+ vectors	extinct – spontaneous	1956	2.6	0.00
Luxembourg *	+ vectors	extinct – spontaneous	19th century	2.5	0.00
Macao	+ vectors	extinct	~1960	3.3	0.00
Macedonia	+ vectors	extinct	1964	3.9	0.00

Madagascar	+ vectors	endemic		5.1	8660.00
Malawi	+ vectors	endemic		5.8	33200.00
Malaysia	+ vectors	endemic		4.5	54.60
Maldives *	eradicated	extinct	1984	7.1	0.00
Mali	+ vectors	endemic		5.6	4590.00
Malta	+ vectors	extinct	1900's	3.2	0.00
Marshall Islands	no vectors	never endemic		7.7	0.00
Martinique *	+ vectors	extinct	~1960	3.3	0.00
Mauritania	+ vectors	endemic		7.6	9800.00
Mauritius *	+ vectors	endemic	2000	4.2	1.00
Mayotte *	+ vectors	endemic		4.6	754.00
Mexico	+ vectors	endemic		4·4	7.38
Micronesia, Federated States	+ vectors	endemic		6·7	0.00
Moldova *	+ vectors	extinct – spontaneous	1960	3·4	0.00
Monaco	no vectors	never endemic		2.3	0.00
Mongolia *	+ vectors	never endemic		4.8	0.00
Montenegro	+ vectors	extinct	1959	3.8	0.00
Montserrat	+ vectors	extinct	1952	2.1	0.00
Morocco *	+ vectors	extinct	2005	5.3	0.01
Mozambique	+ vectors	endemic		4.9	18360.00
Myanmar	+ vectors	endemic		4.8	1250.00
Namibia	+ vectors	endemic		5.1	27420.00
Nauru	no vectors	never endemic		6.2	0.00
Nepal	+ vectors	endemic		4.3	31.20
Netherlands	+ vectors	extinct	1961	2.3	0.00

Netherlands Antilles *	+ vectors	extinct	~1940	3.0	0.00
New Caledonia	no vectors	never endemic		5.2	0.00
New Zealand	no vectors	never endemic		2.6	0.00
Nicaragua	+ vectors	endemic		5.6	470.00
Niger	+ vectors	endemic		6.4	6020.00
Nigeria	+ vectors	endemic		4.9	2160.00
Niue	no vectors	never endemic		3.4	0.00
Norfolk Island	no vectors	never endemic		2.2	0.00
Northern Mariana Islands *	imported	never endemic		3.7	0.00
Norway *	+ vectors	extinct – spontaneous	1956	2.2	0.00
Oman	+ vectors	endemic		6.7	0.25
Pakistan	+ vectors	endemic		6.8	57.20
Palau	no vectors	never endemic		5.7	0.00
Palestine (Gaza + West Bank) *	eradicated	extinct	1966	7.2	0.00
Panama	+ vectors	endemic		4.2	35.10
Papua New Guinea	+ vectors	endemic		6.5	1520.00
Paraguay	+ vectors	endemic		5.3	130.00
Peru	+ vectors	endemic		5.9	270.00
Philippines	+ vectors	endemic		5.0	48.00
Pitcairn	no vectors	never endemic		5.3	0.00
Poland	+ vectors	extinct – spontaneous	1955	3.1	0.00
Portugal	+ vectors	extinct	1958	3.0	0.00
Puerto Rico	+ vectors	extinct	1962	3.0	0.00
Qatar	no vectors	never endemic		7.1	0.00
Reunion *	+ vectors	extinct	1979	3.3	0.00

Romania	+ vectors	extinct	1962	2.8	0.00
Russia *	+ vectors	extinct	1963	2.8	0.00
Rwanda	+ vectors	endemic		5.2	11860.00
Samoa	no vectors	never endemic		8.2	0.00
San Marino	no vectors	never endemic		2.6	0.00
Sao Tome & Principe	+ vectors	endemic		5.2	29190.00
Saudi Arabia	+ vectors	endemic		6.1	22.80
Senegal	+ vectors	endemic		8.7	12490.00
Serbia	+ vectors	extinct	1964	3.2	0.00
Seychelles*	no vectors	never endemic		5.8	0.00
Sierra Leone	+ vectors	endemic		6.1	9540.00
Singapore	+ vectors	extinct	1982	3.7	0.00
Slovakia	+ vectors	extinct – spontaneous	1958	2.9	0.00
Slovenia	+ vectors	extinct	1964	3.1	0.00
Solomon Islands	+ vectors	endemic		6.3	15540.00
Somalia	+ vectors	endemic		5.8	120.00
South Africa *	+ vectors	endemic		3.8	150.00
Spain	+ vectors	extinct – spontaneous	1961	2.9	0.00
Sri Lanka	+ vectors	endemic		4.2	1130.00
St Helena	no vectors	never endemic		3.8	0.00
St Kitts & Nevis	+ vectors	extinct	1950's	3.4	0.00
St Lucia	+ vectors	extinct	1959	3.9	0.00
St Pierre & Miquelon *	no vectors	occasional	19th century	3.5	0.00
St Vincent & Grenadines	+ vectors	extinct	~1952	4.3	0.00
Sudan	+ vectors	endemic		6.1	13780.00
Suriname	+ vectors	endemic		4.1	3090.00

Swaziland	+ vectors	endemic		6.3	4360.00
Sweden	+ vectors	extinct – spontaneous	1933	2.1	0.00
Switzerland	+ vectors	extinct – spontaneous	1910's	2.3	0.00
Syria	+ vectors	endemic		5.6	0.04
Taiwan	+ vectors	extinct	1973	3.2	0.00
Tajikistan *	+ vectors	endemic	(~1963) +1994	5.7	310.00
Tanzania	+ vectors	endemic		4.9	20650.00
Thailand *	+ vectors	endemic		3.9	130.00
Timor-Leste	+ vectors	endemic		5.7	7100.00
Togo	+ vectors	endemic		6.0	8730.00
Tokelau	no vectors	never endemic		5.9	0.00
Tonga	no vectors	never endemic		5.5	0.00
Trinidad & Tobago *	+ vectors	extinct	1962	3.8	0.00
Tunisia	+ vectors	extinct	1979	4.7	0.00
Turkey	+ vectors	endemic		4.6	16.90
Turkmenistan *	+ vectors	endemic	(1960) +1998	5.2	0.40
Turks & Caicos Islands	no vectors	never endemic		3.3	0.00
Tuvalu	no vectors	never endemic		7.7	0.00
Uganda	+ vectors	endemic		5.4	15130.00
Ukraine *	+ vectors	extinct – spontaneous	1956	3.2	0.00
United Arab Emirates	+ vectors	extinct	2000	6.2	0.00
United Kingdom	+ vectors	extinct – spontaneous	1963	2.3	0.00
United States	+ vectors	extinct	1951	2.6	0.00
Uruguay *	+ vectors	extinct	1900's	3.1	0.00
Uzbekistan *	+ vectors	endemic	(1961) +1999	5.1	0.19
Vanuatu	+ vectors	endemic		5.6	3260.00

Venezuela	+ vectors	endemic		5.7	120.00
Viet Nam	+ vectors	endemic		5.0	79.00
Virgin Islands UK *	+ vectors	extinct	1950's	4.4	0.00
Virgin Islands US *	+ vectors	extinct	1950's	2.6	0.00
Wallis & Futuna	no vectors	never endemic		3.0	0.00
Western Sahara *	+ vectors	endemic		6.2	1.00
Yemen	+ vectors	endemic		7.1	7740.00
Zambia	+ vectors	endemic		5.1	10940.00
Zimbabwe	+ vectors	endemic		4.4	12130.00

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Table A2. Population density, GDP per capita, urbanization, slum, Muslims, female literacy, and forest coverage

Country	Population density (people per km²)	GDP per capita (US $)	Urban % of the popu-lation	Slum % of the whole population	Muslim % of the population	Female literacy % (over 15 years)	Forest coverage %
Afghanistan	44.2	(2001) 102	21.30	20.98	99.00	28.1	1.56
Albania	123.3	1202	41.80	no data	79.90	87.0	27.00
Algeria	13.5	1796	59.80	7.06	99.00	70.0	0.90
American Samoa	265.3	(C) 8000	88.80	no data	0.00	97.0	82.00
Andorra	149.6	(2003) 27501	92.30	no data	0.00	100.0	34.00
Angola	9.2	639	50.00	41.55	25.00	67.0	47.91
Anguilla	135.4	(C) 19000	100.00	40.60	0.00	95.0	71.00
Antigua & Barbuda	154.0	8611	37.30	2.57	0.00	86.0	20.00

Argentina	14.1	7694	89.20	29.53	2.00	97.0	12.15
Armenia	100.6	621	65.10	no data	0.00	99.0	10.25
Aruba	367.9	20502	46.70	0.93	0.00	97.0	2.00
Australia	2.6	21768	86.90	(0.76)	1.00	99.0	21.00
Austria	97.5	23866	65.80	(0.26)	0.00	99.0	46.00
Azerbaijan	90.9	655	50.90	no data	93.40	99.0	10.81
Bahamas	21.5	18136	88.80	1.78	0.00	96.0	37.00
Bahrain	976.9	12262	94.60	1.89	81.00	89.0	0.01
Bangladesh	964.3	335	23.20	19.86	89.00	43.0	5.99
Barbados	646.5	10168	49.90	0.50	0.00	99.7	5.00
Belarus	49.7	1273	70.00	no data	0.00	99.7	38.00
Belgium	339.0	22666	97.10	(0.18)	0.00	99.0	22.00
Belize	11.9	3331	47.70	29.57	0.00	94.0	71.98
Benin	66.0	339	38.40	32.10	0.00	33.0	22.49
Bermuda	1224.1	56457	100.00	no data	0.00	98.0	19.00
Bhutan	46.8	762	9.60	4.23	5.00	47.0	81.81
Bolivia	7.9	1010	61.80	37.88	0.00	87.0	54.70
Bosnia & Herzegovina	84.9	1491	43.20	no data	0.00	95.0	43.00
Botswana	2.8	3270	53.20	32.29	0.00	80.0	21.55
Brazil	21.6	3701	81.20	29.72	0.20	86.4	57.92
Brunei	63.3	17996	71.10	1.42	67.00	94.0	50.00
Bulgaria	67.7	1601	68.90	no data	14.00	99.0	30.00
Burkina Faso	48.0	224	16.50	12.62	50.00	27.0	25.21
Burundi	271.0	110	8.60	5.62	20.00	52.0	7.14
Cambodia	73.6	294	16.90	12.20	1.00	74.0	63.75

Cameroon	35.0	635	50.00	33.50	55.00	79.0	47.00
Canada	3.3	23560	79.40	(0.11)	0.50	99.0	31.00
Cape Verde	102.9	1211	53.40	37.17	0.00	77.0	20.33
Cayman Islands	166.0	29547	100.00	2.00	0.00	* 98.0	46.00
Central Africa	6.7	256	37.60	34.74	55.00	51.0	36.76
Chad	7.3	165	23.40	23.19	54.00	48.0	9.59
Chile	20.9	4878	85.90	7.39	0.00	96.0	21.00
China	135.7	949	35.80	13.53	11.00	91.0	18.49
Christmas Island	3.0	no data	0.01	no data	0.00	no data	63.00
Cocos (Keeling) Island	44.4	no data	0.01	no data	0.00	no data	20.00
Colombia	37.1	2523	71.20	15.52	0.00	93.0	53.39
Comoros	350.2	374	33.80	20.69	98.00	57.0	4.30
Congo (Brazzaville) Republic	10.2	1061	58.30	52.53	15.00	84.0	65.97
Congo (Kinshasa) Democratic Republic	25.1	85	29.80	14.75	10.00	66.0	57.66
Cook Islands	88.7	(C, 2001) 5000	65.20	no data	0.00	95.0	68.00
Costa Rica	77.4	4057	59.00	7.55	0.00	96.0	46.50
Cote d'Ivoire (Ivory Coast)	52.5	603	43.00	29.20	55.00	51.0	32.03
Croatia	79.5	4817	55.60	no data	0.00	99.0	38.00
Cuba	102.0	2757	75.60	1.51	0.00	97.0	22.00
Cyprus	83.9	13424	68.60	no data	33.00	98.0	19.00

Czech Republic	129.9	5521	74.00	no data	0.00	99.0	33.00
Denmark	125.6	29993	85.10	(0.14)	0.00	99.0	11.00
Djibouti	20.1	756	83.30	no data	94.00	68.0	0.26
Dominica	93.4	3802	71.10	9.95	0.00	* 94.0	64.00
Dominican Republic	183.0	2718	62.40	23.46	0.00	85.0	28.23
Ecuador	48.6	1295	60.30	15.44	0.00	93.0	46.19
Egypt	76.0	1423	42.50	16.96	93.00	58.0	0.06
El Salvador	313.1	2209	58.40	20.56	0.00	80.0	15.40
Equatorial Guinea	6.7	2371	38.80	33.56	25.00	86.0	60.89
Eritrea	37.6	173	17.80	12.44	0.00	59.0	13.01
Estonia	29.7	4144	69.40	no data	0.00	100.0	50.00
Ethiopia	63.3	125	14.90	14.81	65.00	no data	12.15
Faeroe Islands	33.0	23221	36.30	no data	0.00	no data	0.70
Falkland Islands	0.2	(C, 2002) 2500	85.80	1.72	0.00	no data	0.00
Fiji	48.2	2101	48.30	no data	11.00	94.0	1.00
Finland	15.5	23514	61.10	(0.20)	0.00	100.0	66.00
France	110.5	21914	75.80	(0.34)	3.80	99.0	28.00
French Guiana	2.3	(C, 2002) 6000	75.10	9.69	0.00	83.0	96.43
French Polynesia	75.5	14611	52.40	no data	0.00	98.0	30.00
Gabon	5.1	4109	80.10	53.03	0.00	63.0	81.54
Gambia	137.1	323	49.10	32.90	90.00	40.0	39.18
Georgia	68.3	678	52.70	no data	0.00	* 100.0	3.93

Germany	230.9	23114	75.10	(0.61)	2.40	99.0	31.00
Ghana	90.1	255	44.00	30.62	30.00	75.0	25.55
Gibraltar	4827.6	(C) 27600	100.00	no data	10.00	no data	0.00
Greece	80.7	11501	58.80	(0.09)	3.00	98.0	27.00
Greenland	0.0	19004	81.60	15.10	0.00	100.0	0.00
Grenada	258.3	4245	31.00	2.14	0.00	* 96.0	12.00
Guadeloupe	250.2	(C, 2003) 7900	99.60	6.87	0.00	* 90.0	48.00
Guam	304.0	(C) 21000	93.20	no data	0.00	99.0	48.00
Guatemala	107.6	1718	45.10	27.87	0.00	71.0	38.60
Guinea	37.6	371	31.00	22.41	85.00	36.0	28.08
Guinea Bissau	38.4	165	29.70	27.74	70.00	42.0	58.69
Guyana	3.5	942	28.60	1.40	15.00	99.0	70.25
Haiti	286.2	424	35.60	30.51	0.00	53.0	4.06
Honduras	62.3	1141	44.40	8.04	0.00	76.0	48.27
Hong Kong	6219.4	25375	100.00	2.00	1.00	94.0	16.00
Hungary	107.8	2101	64.60	no data	0.00	99.0	20.00
Iceland	2.9	309.1	92.30	no data	0.00	99.0	0.37
India	336.4	4.3	27.70	15.37	12.00	60.0	21.33
Indonesia	126.1	804	42.00	9.70	86.10	88.0	50.89
Iran	41.1	1584	64.20	28.38	98.00	79.0	6.72
Iraq	58.5	1030	67.80	38.44	97.00	40.0	1.87
Ireland	56.5	25380	59.10	(0.40)	0.00	99.0	9.00
Israel	295.3	19836	91.40	1.83	0.00	95.0	8.00
Italy	192.7	19269	67.20	(0.03)	1.00	99.0	31.00
Jamaica	246.7	3479	51.80	18.49	0.00	88.0	31.00
Japan	336.9	36789	65.20	no data	0.00	99.0	66.00

Jordan	62.8	1764	80.40	12.62	95.00	91.0	1.00
Kazakhstan	5.5	1229	56.30	no data	57.00	98.0	1.00
Kenya	56.6	404	19.70	13.93	29.50	85.0	6.15
Kiribati	124.6	812	43.00	no data	0.00	no data	2.00
Korea North	184.9	(C) 1000	60.20	0.42	0.00	99.0	55.56
Korea South	486·5	11347	79.60	29.45	0.00	98.0	63.20
Kosovo	179·3	1088	40·00	no data	90.00	no data	47.00
Kuwait	126.7	17223	98.20	2.95	85.00	84.0	0.30
Kyrgyzstan	25.4	279	35.40	no data	75.00	99.0	4.29
Laos	25.6	321	18.90	12.49	0.00	66.0	69.81
Latvia	35.7	3302	68.10	no data	0.00	100.0	45.00
Lebanon	364.2	4576	86.00	43.00	60.00	87.0	13.00
Lesotho	67.2	395	17.80	10.15	10.00	85.0	0.50
Liberia	28.4	199	54.30	30.25	30.00	* 58.0	34.88
Libya	3.2	6340	83.10	29.25	97.00	83.0	0.10
Liechtenstein	206.3	75583	15.10	no data	0.00	100.0	44.00
Lithuania	55.3	3267	67.00	no data	0.00	100.0	3.00
Luxembourg	179.0	46458	83.80	(0.17)	0.00	100.0	34.00
Macao	16300.4	13839	100.00	2.00	0.00	* 95.0	0.00
Macedonia	79.3	1783	64.90	no data	0.00	96.0	35.00
Madagascar	29.8	254	26.00	24.15	20.00	69.0	22.18
Malawi	104.7	147	15.10	13.76	35.00	63.0	30.11
Malaysia	71.2	4030	61.80	1.24	60.40	89.0	65.27
Maldives	1137.6	2293	27.50	no data	100.00	97.0	3.00
Mali	8.9	230	27.90	26.00	90.00	46.0	10.47
Malta	1257.5	9981	93.40	no data	14.00	93.0	0.00

Marshall Islands	319.6	2097	65.80	no data	0.00	94.0	0.00
Martinique	381.2	(C, 2001) 10700	97.80	1.96	0.00	* 98.0	41.00
Mauritania	2.9	415	40.00	37.72	99.99	42.0	0.31
Mauritius	598.2	3861	42.70	no data	19.50	86.0	18.63
Mayotte	498.3	(C, 2003) 2600	60.00	no data	0.00	* 92.0	3.00
Mexico	53.4	5935	74.70	14.64	0.00	92.0	33.36
Micronesia Federated States	154.1	2109	22.30	no data	0.00	89.0	90.00
Moldova	131.4	354	46.10	no data	0.00	99.0	10.00
Monaco	16842.1	82741	100.00	no data	0.00	99.0	0.40
Mongolia	1.8	456	56.60	36.73	0.00	98.0	7.00
Montenegro	44.2	1490	55.00	no data	0.00	* 96.0	54.00
Montserrat	90.2	(C, 2002) 3400	11.00	0.97	0.00	* 97.0	40.00
Morocco	70.2	1270	55.10	18.02	99.00	52.0	9.44
Mozambique	23.9	233	30.70	28.89	29.00	48.0	24.34
Myanmar	68.8	(C) 1500	28.00	7.39	10.00	85.0	51.07
Namibia	2.5	2143	32.40	12.28	5.00	84.0	9.74
Nauru	613.2	(C) 5000	100.00	no data	0.00	no data	0.00
Nepal	183.9	225	13.40	no data	4.00	49.0	0.26
Netherlands	392.9	24180	76.80	(0.16)	1.50	99.0	9.00
Netherlands Antilles	272.5	(C) 11400	69.30	0.69	0.00	* 97.0	1.25
New Caledonia	11.5	12580	61.90	no data	0.00	91.0	39.00

New Zealand	14.8	13336	85.70	no data	0.00	99.0	30.00
Nicaragua	40.8	772	57.20	46.27	0.00	68.0	42.49
Niger	10.0	163	16.20	15.58	90.00	18.0	1.12
Nigeria	136.1	368	43.90	34.77	50.00	68.0	14.22
Niue	8.4	(C) 3600	33.70	no data	0.00	95.0	57.00
Norfolk Island	52.0	no data	0.01	no data	0.00	no data	14.00
Northern Mariana Islands	170.6	(C) 12500	93.30	no data	0.00	97.0	74.00
Norway	14.1	37472	76.10	no data	0.00	100.0	29.00
Oman	9.4	8271	71.60	43.32	93.00	76.0	0.01
Pakistan	180.9	536	33.10	24.36	97.00	49.0	2.40
Palau	40.7	6266	69.60	no data	0.00	92.0	81.00
Palestine (Gaza + West Bank)	523.1	(C) 1500	71.50	42.90	98.00	92.0	1.00
Panama	41.2	3938	65.80	20.27	4.00	93.0	57.43
Papua New Guinea	11.7	654	13.20	no data	0.00	65.0	65.10
Paraguay	15.2	1322	55.30	13.82	0.00	94.0	47.62
Peru	21.4	2049	71.60	48.76	0.00	88.0	53.86
Philippines	287.4	977	58.50	25.80	12.00	93.0	24.88
Pitcairn	1.4	no data	0.01	no data	0.00	no data	77.00
Poland	123.4	4454	61.70	no data	0.00	100.0	29.00
Portugal	113.9	11443	54.40	(0.02)	0.00	93.0	39.00
Puerto Rico	438.3	16004	94.60	1.89	0.00	* 94.0	45.00
Qatar	73.5	28793	94.90	1.90	77.50	89.0	0.00

Reunion	305.5	(C, 1999) 4800	89.90	no data	20.00	* 90.0	35.00
Romania	93.8	1651	54.60	no data	20.00	98.0	27.00
Russia	8.4	1775	73.40	no data	0.00	100.0	47.00
Rwanda	312.8	218	13.80	12.13	0.00	70.0	13.06
Samoa	62.9	1391	21.50	no data	0.00	100.0	60.00
San Marino	473.9	(C) 32000	93.50	no data	0.00	96.0	0.00
Sao Tome & Principe	181.8	(2001) 536	53.40	1.07	0.00	79.0	26.97
Saudi Arabia	12.0	9128	79.80	15.80	100.00	79.0	1.27
Senegal	58.1	474	40.60	31.02	94.00	40.0	45.23
Serbia	105.8	809	51.60	no data	0.00	* 96.0	26.00
Seychelles	179.0	7579	51.00	1.02	0.00	92.0	88.00
Sierra Leone	79.9	150	37.00	35.45	60.00	* 30.0	39.74
Singapore	6246.8	23019	100.00	no data	0.00	93.0	3.00
Slovakia	110.6	5326	56.30	no data	0.00	100.0	39.00
Slovenia	99.2	9999	50.80	no data	0.00	100.0	61.00
Solomon Islands	18.5	1047	15.70	no data	0.00	no data	83.57
Somalia	13.0	(C) 600	33.30	32.33	99.90	* 3.0	11.79
South Africa	36.5	3020	56.90	18.89	2.00	86.0	7.54
Spain	79.6	14422	76.30	no data	0.00	98.0	32.00
Sri Lanka	303·4	873	15.70	2.14	9.00	92.0	31.73
St Helena	13.9	(C, 1998) 2500	39.20	0.78	0.00	97.0	5.00
St Kitts & Nevis	146.3	7366	32.80	1.64	0.00	* 98.0	19.00
St Lucia	266.1	4536	28.00	3.33	0.00	* 90.0	28.00
St Pierre &	28.9	(C, 2001) 6900	88.90	7.73	0.00	99.0	12.00

Miquelon							
St Vincent & Grenadines	300.5	3143	44.40	2.22	0.00	* 96.0	26.00
Sudan	15.6	354	36.10	30.94	70.00	61.0	28.13
Suriname	2.7	1910	72.10	4.97	25.00	88.0	90.20
Swaziland	65.5	1380	23.30	no data	10.00	82.0	29.83
Sweden	20.4	27879	84.00	(0.09)	0.00	99.0	61.00
Switzerland	180.5	34787	73.10	no data	0.00	99.0	29.00
Syria	97.3	1170	50.10	5.21	90.00	77.0	2.33
Taiwan	628.7	(C) 17400	80.00	no data	0.00	* 96.0	58.00
Tajikistan	49.0	139	25.90	no data	97.00	99.0	2.87
Tanzania	38.2	274	22.30	20.54	65.00	78.0	39.49
Thailand	124.2	1968	31.10	0.62	14.00	93.0	28.87
Timor-Leste	51.4	388	24.50	2.94	20.00	* 59.0	58.48
Togo	92.5	253	36.60	29.50	55.00	61.0	8.56
Tokelau	138.6	(C) 1000	0.01	no data	0.00	no data	0.00
Tonga	146.7	1913	23.20	no data	0.00	99.0	6.00
Trinidad & Tobago	210.3	6296	10.80	3.46	12.00	99.0	44.00
Tunisia	61.0	2033	63.40	2.35	98.00	74.0	6.00
Turkey	87.9	4011	64.70	11.58	99.80	87.0	12.83
Turkmenistan	10.0	645	45.10	no data	89.00	99.0	8.46
Turks & Caicos Islands	40.2	(C) 9600	43.50	0.87	0.00	98.0	68.00
Tuvalu	429.7	(C) 1100	46.00	no data	0.00	no data	38.00
Uganda	109.3	253	12.10	11.25	36.00	70.0	15.02
Ukraine	78.4	636	67.10	no data	0.00	100.0	16.00

United Arab Emirates	32.5	21801	77.40	1.55	76.00	78.0	4.00
United Kingdom	248.5	25089	89.40	(0.26)	2.70	99.0	12.00
United States	30.8	35081	79.10	(1.24)	1.50	99.0	31.00
Uruguay	19.3	6914	91.30	1.83	0.00	98.0	8.00
Uzbekistan	57.5	558	37.30	no data	88.00	99.0	7.15
Vanuatu	16.7	1480	21.70	no data	0.00	74.0	36.10
Venezuela	27.3	4819	91.10	37.08	0.00	93.0	53.63
Viet Nam	249.7	402	24.30	11.52	0.00	90.0	35.35
Virgin Isl. UK	143.2	(C) 16000	57.30	no data	0.00	no data	26.00
Virgin Isl. US	308.8	(C) 15000	92.60	no data	0.00	no data	29.00
Wallis & Futuna	58.4	(C) 2000	0.01	no data	0.00	50.0	0.00
Western Sahara	1.1	(C, 2007) 2500	91.20	1.82	99.00	no data	4.01
Yemen	37.2	519	25.40	16.54	99.00	50.0	1.02
Zambia	14.7	309	34.80	25.75	15.00	81.0	59.36
Zimbabwe	30.9	594	33.80	1.15	15.00	91.0	48.89

A2. Comments on the statistics in alphabetical order according to country

Afghanistan

There are conflicting estimates for the average household size in Afghanistan. Household size is based on regional samples or from refugee camps. Statistics Finland presents values between 4.8 and 5.2 for the years 2001 – 2004 (OSF 2006). In 1986 and 1988 the average household size among Afghan refugees in Pakistan was estimated to 8.5 and 6.2 respectively (Yusuf 1990). The

Afghan government 2009 presents a household size of 7.3 for the year 2007/8 (Central Statistics Organization of the Afghan government 2009). A medium value of 6.0 is used.

Antigua & Barbuda

Historical malaria has been recorded in Antigua where *Anopheles albimanus* is common (Faran 1980). This vector has only once in 1955, probably occasionally, been found in Barbuda (Faran 1980). Endemic malaria was eradicated from Antigua in 1952 (Uttley 1961).

Argentina

Statistics on population and household size on provincial level are based on Population Census 2001 (INDEC 2001). Historically malaria has occurred in 17 provinces of Argentina and disappeared from 13 provinces (Curto et al. 2003). Malaria has never occurred in the five southernmost provinces and La Pampa and Entre Rios. In recent decades malaria has increased in Misiones. Malaria has disappeared from all provinces with average household size lower than four (see fig.1).

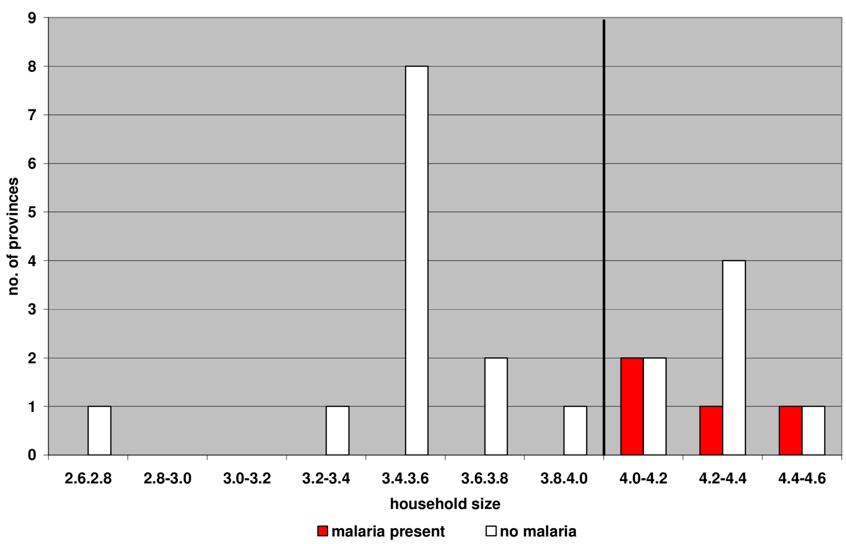

Figure A2.1. Malaria and household size in the provinces of Argentina.

Armenia

See comments for Russia.

Azerbaijan

See comments for Russia.

Bahamas

Endemic malaria was eradicated in 1960's (Rawlins et al. 2008). An outbreak of malaria in 2006 has been reported (CDC 2006).

Bahrain

The last case of endemic malaria was in 1979 (Amin 1989).

Barbados

Despite the lack of indigenous vectors a malaria epidemic occurred in 1927 – 1929 because of introduction of the vector *Anopheles albimanus* with fishing boats. It is assumed that labourers returning from malarious regions outside Barbados initiated the epidemics. The vector was soon eradicated from Barbados (Fonaroff 1966).

Belarus

See comments for Russia.

Belgium

The last case of indigenous malaria in Belgium was recorded in 1938 (Bruce-Chwatt and de Zulueta 1980). Malaria deaths in Belgium seems, however, to end with a few cases still in 1950 (Devos 2006). They were probably infections of *Plasmodium falciparum* and imported cases. The year 1938 is adopted as the last year of indigenous malaria in Belgium.

Brazil

Household size on provincial level is published in Demographic Census in 2000 in Brazil (see fig. 4) (IBGE 2000).

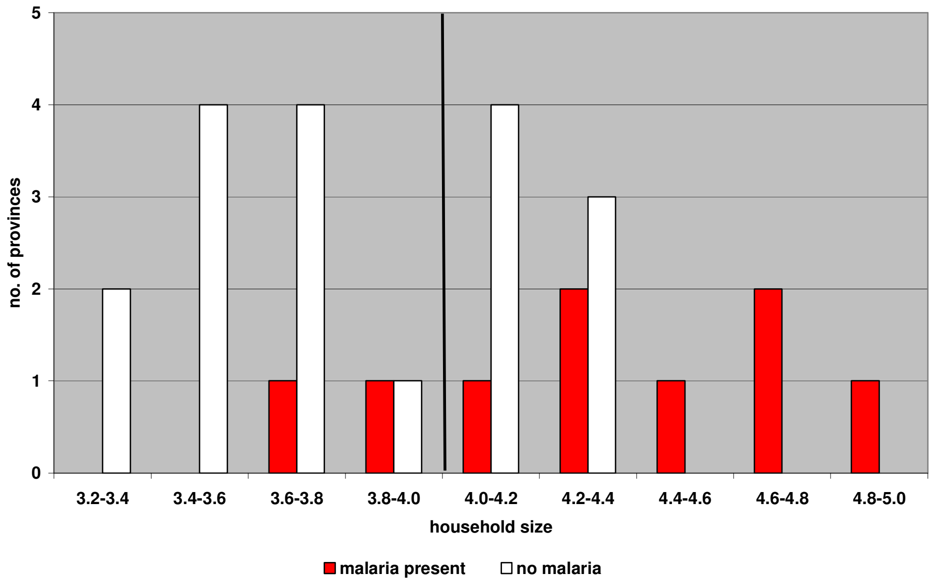

Figure A2.2. Malaria and household size in the 27 provinces of Brazil.

Two malarious provinces have an average household size lower than four, Mato Grosso (3.78) and Rondonia (3.92). Malaria in Mato Grosso (4173 cases in 2000) can be characterized as frontier malaria as agriculture was extended in the northern part in the 1980's. People live in provisional housing conditions. In the same area placer gold was discovered resulting in a heavy population growth because of immigration of pan miners from other parts of malarious regions (Atanaka-Santos et al. 2007). Rondonia (95295 malaria cases in 2000, mainly in rural settings where the average household size is 4.1) has experienced a similar development. The population has increased by a factor of ten in 1975 – 2000 as a result of heavy immigration from other regions of Brazil. New agricultural and mining settlements have emerged. Provisional housing conditions and a highly mobile population increase the spread of malaria (Camargo et al. 1994). The formal average household size is a too crude measure for the local housing conditions.

Brunei

Last reported case of indigenous malaria was in 1971 (Paik 1990).

Canada

Malaria occurred in most provinces of Canada in the 19th century within the northern distribution limits of the assumed vector *Anopheles earlei* (O'Rourke 1959). Malaria occurred in Yukon at least until December in 1898 (Hitchcock 1899). Although no specific year for the disappearance of malaria can be found, it is probable that malaria cases still occurred in Canada during the first decade of the 20th century (Fisk 1931). Malaria occurred then only along the northern shore of Lake Ontario (Deadrick 1909). Tentatively 1910 is adopted as the year of last malaria case.

Cayman Islands

Malaria disappeared in the 1950's (Cayman Islands government 2010). Eradication campaigns were carried through 1958 – 1962 (Rawlins et al. 208). *Anopheles albimanus* and *A. grabhamii* are common (Brunt 1994).

Chile

Last autochthonous case of malaria was recorded in 1945 (Schenone et al. 2002).

China

China is one of seven countries with a low average household size (3.6) where malaria is endemic. A detailed analysis on sub-regional level could not be performed because high resolution demographic statistics are not available and statistics on household size are partly based on sub-samples of the population. Cross-checking of various tables in the China Population Statistics Yearbook 2002 shows that figures do not add up with each other (China Statistics Press 2002). As a consequence available statistics cannot directly be compared with other countries.

Malaria prevalence in China is very low, about 1.5 cases per 100000 people (Roll Back Malaria, WHO, UNICEF 2005). Most of the malaria cases occur in mountainous forest regions and rural regions (Gideon 2007). Malaria has been reported in 28 of 31 provinces during 2002 – 2007 according to annual reports on malaria situation in China (Sheng et al. 2003, Zhou et al. 2005, Zhou et al. 2006a, Zhou et al. 2006b, Zhou et al. 2007, Zgou et al. 2008).

The mean value of malaria prevalence in 7 provinces where 92 % of all cases occurred in 2002 was 19 cases per 100000 people. The value of the remaining 24 provinces was only 0.27 cases per 100000 people. The average household size was 4.1 for the first seven provinces and 3.5 for the remaining 24 provinces. The corresponding values for rural regions are 4.1 and 3.6. This indicates that malaria is in China strongly associated with high household size.

Cuba

Five species of *Anopheles* are known from Cuba (Carr and Hill 1942). Malaria has not been recorded on Cuba since 1967. WHO officially certified Cuba as malaria free in 1973 (Rivero et al. 2008a).

Cyprus

Eight species of *Anopheles* are known from Cyprus (Violaris et al. 209). In 1934 *A. hyrcanus, A. multicolor* and *A. sacharovi* was recorded. *A. hyrcanus* and *A. multicolor* have not been recorded later. *A. sacharovi* was assumed to be the main vector but it was not eradicated (de Zulueta 1990).

Denmark

The last case of endemic malaria was reported in 1945 (Statistiske department 1947).

Djibouti

Malaria was known in Djibouti (former French Somaliland) in the beginning of the 20th century. There was an epidemic in 1901 in the suburbs of the town of Djibouti. In about 1910 both malaria and its vector (*Anopheles arabiensis*) was expected to have disappeared for an undetermined reason (Manguin et al. 2008). In the years 1926 – 1930 about 100 cases, of which 30 cases in 1930, were treated in Djibouti (League of Nations 1932). It was also noted that the patients came from outside the town of Djibouti.

In 1950's Djibouti was considered a highly malarious country where about half of the population got protection against malaria (Russell 1956, Russell 1959). A conflicting report mentions that eradication had been achieved and refers to 1960 (Cannan 1962). It was probably an overstatement, because in 1965 malaria was declining but not yet eradicated (Lysenko and Semaschko 1968).

The status of malaria is uncertain until 1970's when malaria epidemics returned in the same place as in 1901. All treated cases between 1910 and 1970 have been considered imported. They mostly occurred along the railway from Djibouti to Dire Dawa in Ethiopia (Manguin et al. 2008). If vector species have occurred in that time then malaria could still be considered continuously endemic with low prevalence.

Dominica

Last indigenous malaria case was reported in 1960's (Rivero et al. 2008a, PAHO 2007).

Dominican Republic

A report that malaria was certified malaria-free in the 1960's has been withdrawn because of a mistake by the editorial board (Rivero et al. 2008b). The information concerns Dominica and not the Dominican Republic.

Egypt

World Malaria Report 2005 does not mention malaria cases in 1998 – 2003. Malaria, however, has been persistent in the El-Fayoum governorate (Bassiouny et al. 1999a, Bassiouny et al. 1999b, Bassiouny 2001, Dahesh et al. 2009a, Dahesh et al. 2009b, Hassan et 2003). Accordingly, malaria is considered to have been present in Egypt in 2000.

Estonia

See comments for Russia.

Finland

The last indigenous cases were reported in 1954 (Hulden and Hulden 2009). Malaria trends in relation to temperature trends and household size trends are shown in Figs. 3 and 4.

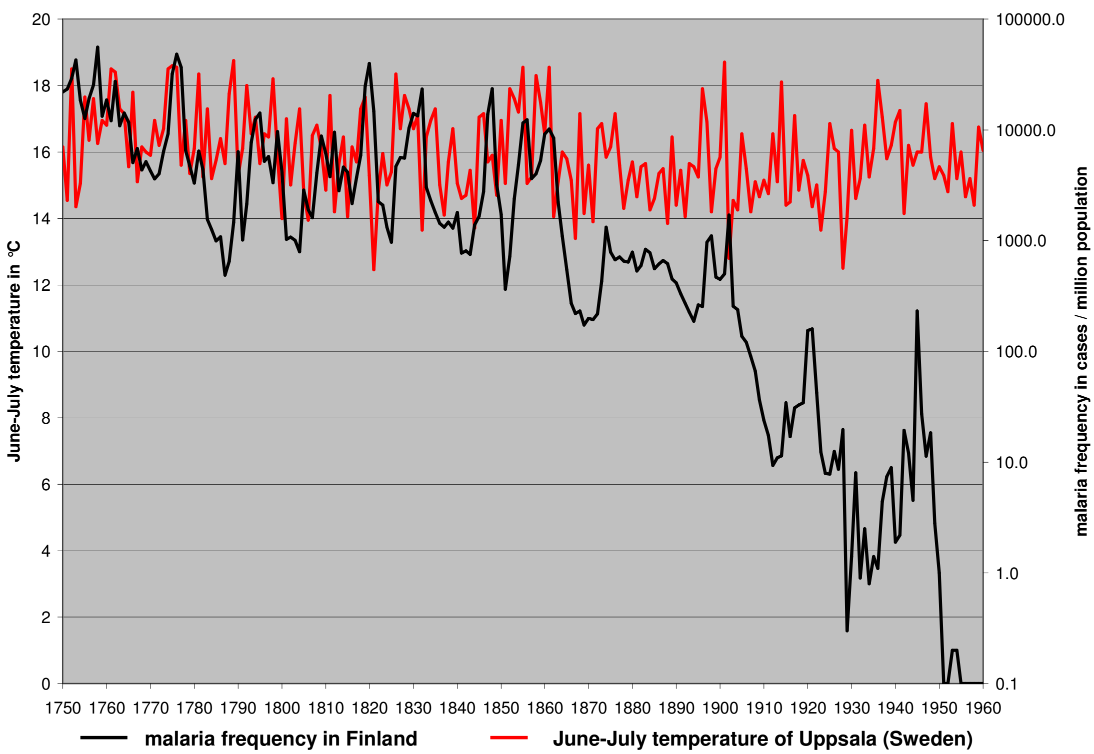

Figure A2.3. Malaria and June-July mean temperature trends in Finland in 1750 – 1960 (Huldén and Huldén 2009)

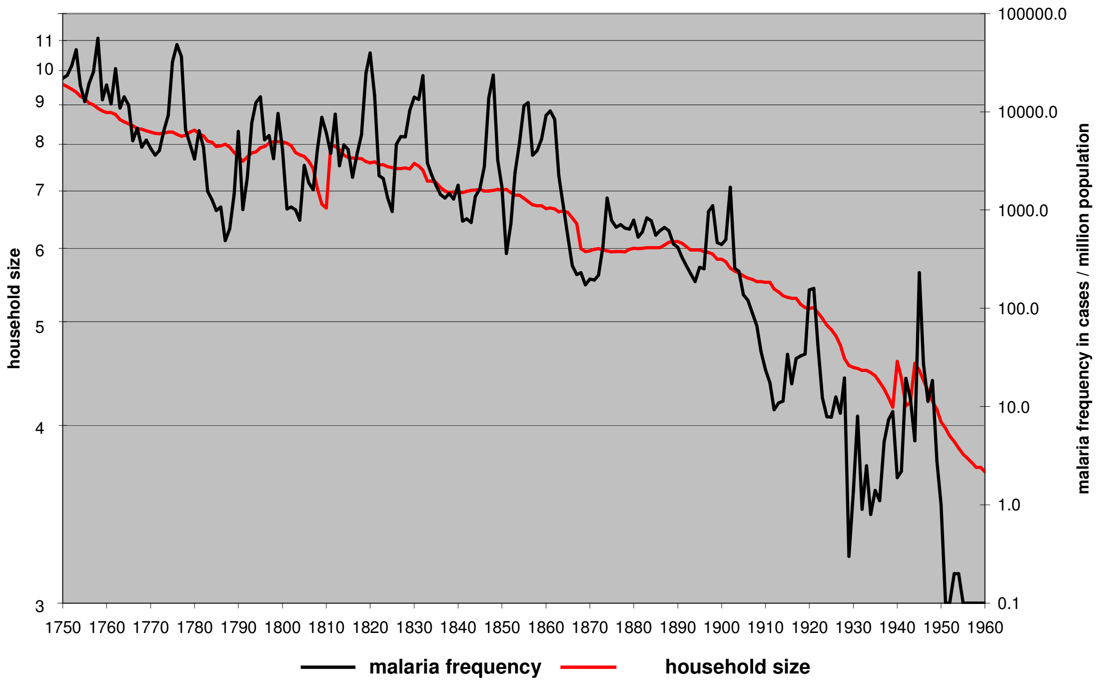

Figure A2.4. Malaria and household size trends in Finland in 1750 – 1960 (Huldén and Huldén 2009)

France

Eradication campaigns were arranged in Corsica but not on the mainland. The last indigenous malaria cases were reported in 1943 on the mainland and about 1970 in Corsica (Bruce-Chwatt and de Zulueta 1980). A case of autochthonous vivax malaria was reported in Corsica in 2006 (Armengaus et al. 2009).

French Guiana

Despite a low average household size (3.4) the country has a high malaria frequency. The distribution of malaria is uneven with 97.6 % of the malaria cases occurring in the inland regions with only 20 % of the population (Chaud et al. 2006). Only 2.4 % of the malaria cases have been recorded along the narrow coastal region where 80 % of the population lives. Malaria is prevalent among Amerindians living along the big rivers flowing into the Atlantic Ocean. They have an average household size between 5 and 7 while the coastal population has about 3.0 (Carme 2009, Hustache et al. 2007, Legrand et al. 2008).

Georgia

See comments for Russia.

Gibraltar

Endemic malaria occurred at least in the beginning of the 19th century among the British troupes in Gibraltar (Padiak 2005). The most common vector along the coasts of Spain, *Anopheles atroparvus*, has probably been the vector in Gibraltar (Bueno and Jimenez 2008). Although malaria was highly prevalent in the 1930's in the neighbouring region of Spain there are no reports on malaria in Gibraltar.

Grenada

Grenada was officially declared malaria-free in 1962 by WHO. The last case of *falciparum* malaria was in 1959. Small outbreaks or isolated cases of *Plasmodium malariae* has occurred in 1972, 1975 and 1978 (Tikasingh et al. 1980).

Guadeloupe

Malaria is considered to be eradicated since 1970 (Poinsignon et al. 1999).

Guam

There are no endemic *Anopheles* species on Guam. During World War II and later ten species have occasionally been introduced but probably only one, *A. indefinitus*, is established on the island (Nowell 1976). There have been a few outbreakes of malaria with local transmissions, but most cases have been imported.

Hong Kong

Malaria (mainly *Plasmodium vivax*) was reported as eradicated in 1969 but reappeared (probably relapses) at several occasions in 1971, 1980 – 1983, 1985 and 1988 (Chan 1984, Paik 1990, Epidemiology Bulletin by Department of Health, China 1990). After 1988 only imported cases have been reported (Scientific Committee on vector-borne diseases 2006).

Ireland

There are only few sources of indigenous malaria in Ireland (Ashe et al. 1991). Ague, which usually was attributed to malaria has also been used for other fevers. The reliable records are from 17th to 19th century. There were some deaths from malaria in 1878 – 1881. Malaria is tentatively expected to have disappeared from Ireland in about 1900's. The malarious regions were mainly in the eastern (more sheltered) parts of Ireland (Bayliss 1985).

Israel

The last case of autochthonous malaria was in 1963 (Rubin et al. 2005).

Italy

Malaria disappeared on mainland in 1964 and in Sicily in 1957 (Bruce-Chwatt and de Zulueta 1980).

Jamaica

The last case of malaria was reported in 1958 (Gallup and Sachs 2001).

Japan

The last case of malaria was reported in 1961 (Yagita and Endo 1999).

Jordan

Malaria was eradicated in 1997 (WHO EMRO 2003b).

Kazakhstan

See comments for Russia.

Korea, North & Korea, South

Both North Korea and South Korea (average household size 4.0 and 2.8 in 2000) were declared malaria free in 1979 (Roll Back Malaria, WHO, UNICEF 2005). Malaria (*Plasmodium vivax*) re-emerged in the 1990's which indicates that malaria was not completely eradicated in 1979. The re-emerge has mostly been explained by re-emerging malaria in North Korea which then was spread by mosquitoes into South Korea. A new hypothesis is that increased military forces close to the border caused occasional hypnozoite carriers to become exposed to vectors in field conditions and malaria re-emerged. Soldiers living in barracks for a prolonged time correspond to a high household size. Malaria is expected to prevail as long as positional warfare conditions keep the troupes close to the border (Hulden and Hulden 2008). The average household size for North Korea was estimated to be 4.0 in 2000 (Eberstad and Banister 1992, Courtland et al. 1999, Schwekendiek 2008).

Kuwait

Indigenous malaria has never been recorded in Kuwait. Two potential vector species were recorded in 1994, *A. stephensi* and *A. pulcherrimus* (Salit et al. 1994). The status of these finds is unclear. Kuwait is interpreted as a country lacking vector species in the current study.

Kyrgyzstan

See comments for Russia.

Latvia

See comments for Russia.

Lebanon

The country was considered malaria-free in 1963 (de Zulueta and Muir 1972). Indigenous cases have, however, been recorded later. The last cases of indigenous malaria seem to have been recorded in 1999 (WHO EMRO 2009a).

Lesotho

Indigenous malaria has never been reported in Lesotho. The only *Anopheles* species, *A. demeilloni*, has only once been recorded (Muspratt 1959). It has a large distribution in Eastern and Southern Africa but seems to occur in low frequencies and is not considered to be a malaria vector. Lesotho is interpreted as a country lacking vector species.

Liechtenstein

Wernsdorfer (2002) considered that Liechtenstein might not have had endemic malaria. He was unawared that malaria has been reported from Liechtenstein in the 19th century along Alpine Rhine valley (Büchel 1916). Although there are no records of *Anopheles* in Liechtenstein it is very likely that the same species (*A. claviger* to 1600 m altitude and *A. messeae* to 600 m altitude) that have been collected on the Swiss part of the border along Alpine Rhine also occurs in Liechtenstein (Briegel 1973). The last case of malaria is estimated to be the same as in Switzerland, 1910 (Bucher 1992).

Lithuania

See comments for Russia.

Luxembourg

Endemic malaria has never been documented in the Luxembourg. Three potential, widespread vectors have been recorded: *Anopheles claviger*, *A. maculipennis* s.l. and *A. plumbeus* (Beck et al. 2003). Because malaria has been prevalent in all neighbouring countries (Belgium, France and Germany) in the 19th and 20th century it is highly probable that malaria also has occurred in Luxembourg. In this study malaria is interpreted as having disappeared in the 19th century.

Maldives

The vectors *Anopheles subpictus* and *A. tessellatus* have been reported from Maldives. Both species have been eradicated from the islands and as a consequence malaria disappeared in 1983 (WHO SEAR 2010).

Martinique

Malaria was eradicated in ~1960 (Poinsignon et al. 1999).

Mauritius

Malaria (*P. falciparum* and *vivax*) was regularly imported with migrants from Africa and India since the 18th century. Malaria vectors (*A. arabiensis*, *A.funestus* and *A merus*) were imported from Madagascar with a new fast steamer in 1865 which initiated a local epidemic and malaria became endemic. During malaria eradication operations in 1948 – 1952 *A. funestus* disappeared and the parasite was nearly eliminated. Malaria was reported as eradicated in 1973, but vivax malaria resumed in 1975 (Manguin et al. 2008). After a new eradication program malaria was again declared eradicated in 1995. It re-appeared in 1996 with a few annual cases Tchen et al.

2006). Although there were no cases in 2000 Mauritius is still interpreted in this study as a malarious country. There are no *Anopheles* species and accordingly no malaria on the island of Rodriguez (Julvez 1995).

Mayotte

Malaria was reported as eradicated in 1973, but re-appeared in 1995 with about 1000 cases annually (Tchen et al. 2006).

Moldova

See comments for Russia.

Mongolia

Indigenous malaria has never been recorded in Mongolia. The northern Eurasian vector *Anopheles messeae* is known from several localities in the northern part of the country (Minar 1971, Minar 1976, Minar 1987). The absence of endemic malaria is probably due to the nomadic culture. Most of the original Mongolian population has before urbanization moved regularly several times per year (Zhang et al. 2007). In a cold region like Mongolia the indoor sporogony in the winter season cannot take place in the vector if humans regularly move their tents (yurts) from place to place[7].

Morocco

Malaria was eradicated in 2004 (El Quali et al. 2009). In the analysis Morocco is still considered as a malaria-endemic country in 2000.

Netherlands Antilles

Autochthonous malaria has never been reported from the Netherlands Antilles. In rural regions of Curacao, however, a spleen rate of 1.7% among children was observed in 1946 but malaria parasites were not found. The vector species, *Anopheles pseudopunctipennis* was widespread in Curacao (van der Kuyp 1949). The past status of malaria remains unsettled. In this study malaria is expected to have disappeared in ~1940.

Northern Mariana Islands

There are no indigenous *Anopheles* species on these islands. *A. indefinitus* has been imported after World War II to Saipan Island from Guam (Pratt and Siren 1971). Autochthonous malaria is not known.

Norway

The last case of malaria was reported in 1956 (Central bureau of statistics of Norway 1959).

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[7] The situation in Mongolia can be compared with the situation in Finnish Lapland. The nomadic Saami people did not have malaria while they lived in movable tents made of reindeer hides during winter (Hulden and Hulden 2009)

Palestine

Malaria was eradicated in 1966 and the vectors (*Anopheles pharoensis* and *A. multicolor*) were eradicated in 1991 within the borders of present day Palestine (WHO EMRO 2009b). About 90 % of the fresh water resources in West Bank are controlled by Israel as their property (Palestine Monitor 2010). The only remaining potential habitat for vectors is Wadi Gaza River in Gaza strip. On the other hand at least three primary and five secondary vector species occur in Israel (Margalit and Tahori 1974).

Reunion

Wind driven infected *Anopheles* vectors from Mauritius in 1868 has been suggested as the origin of indigenous malaria in Reunion (Manguin et al. 2008). It is more likely that both the vectors and human malaria carriers came by boat to Reunion in the same way as to Mauritius. Malaria was eradicated in 1979. One autochthonous case was reported in 2000 (Tchen et al. 2006).

Russia

During the Soviet era malaria was reported as eradicated in the 15 republics including the Russian Federation in 1952 – 1970. After 1990, however, malaria re-emerged in many of the former southern republics (see table 3). Malaria re-emerged in countries with a household size of four or more. It may be questioned if malaria ever was completely eradicated in some of these countries.

Between 1992 and 2001 Kazakhstan had 11 isolated cases of autochthonous malaria following an increased number of imported cases. After 2001 there have been no local transmissions of malaria. Kazakhstan is in this study interpreted as a non-malarious country in 2000.

In Turkmenistan there were nearly 200 autochthonous malaria cases in 1998 – 2005. The country was certified malaria free in October 2010 (WHO 2010).

In Estonia three cases in 1952 are accepted as the last endemic cases because they are close in time to the former seven cases in 1949. Two cases from 1969 originated from blood transfusion and are not true endemic cases. One case from 1991, a 26 year old male, had never been abroad and had been defined as locally acquired malaria (Jögiste et al. 2000, Epstein and Järvelaid 2005). In the present study it is, however, not expected to represent an indigenous case because of the long time gap of 39 years to the previous endemic cases.

The average household size in Georgia is rapidly declining. For 2001 there is a value of 4.01 and for 2005 the value of 3.6 (OSF 2010, UNECE 2005). Tentatively a value of 4.0 for 2000 is applied in this study.

Table A3. Malaria re-emergence in the former USSR in the 1990's

Country	**year of presumed eradication**	**household size in 2000**	**year of re-emergence**
Estonia	1952	2.4	no re-emergence

Belarus	1963	2.6	no re-emergence
Lithuania	1956	2.6	no re-emergence
Latvia	1953	2.7	no re-emergence
Russia	1963	2.8	no re-emergence
Ukraine	1956	3.2 (UNECE 2005)	no re-emergence
Moldova	1960	3.4 (UNECE 2005)	no re-emergence
Kazakhstan	1967	3.6 (UNECE 2005)	1992 – 2001, 11 occasional cases
Georgia	1970	4.0	1996 →
Armenia	1964	4.1	1994 →
Kyrgyzstan	1960	4.3 (UNECE 2005)	1996 →
Azerbaijan	1967	4.7	1994 →
Uzbekistan	1961	5.1 (UNECE 2005)	1999 →
Turkmenistan	1960	5.2 (UNECE 2005)	1998 → 2005, 200 autochtonous cases declared malaria free in 2010
Tajikistan	1963	5.8 (UNECE 2005)	1994 →

Seychelles

There were occasional malaria epidemics in 1908 (*Plasmodium vivax* in Aldabra) and 1930-31 (*Plasmodium falciparum* in Assumption and Aldabra) (Mathew 1032). *Anopheles gambiae* has been reported in Aldabra in 1930 and on Assumption Island in 1975 (Hermitte 1931, Bruce-Chwatt 1976). The latter record has recently been interpreted as a contamination of sampling from the African continent (Robert et al. 2011). *Anopheles* populations are only occasional in the Seychelles.

South Africa

Malaria is prevalent in the provinces of KwaZulu-Natal, Limpopo and Mpumalanga in the northern and eastern parts of South Africa with seasonal transmission (Gerritsen et al. 2008). Only four provinces have a household size higher than four (see fig. 3) (Health System Trust 2000).

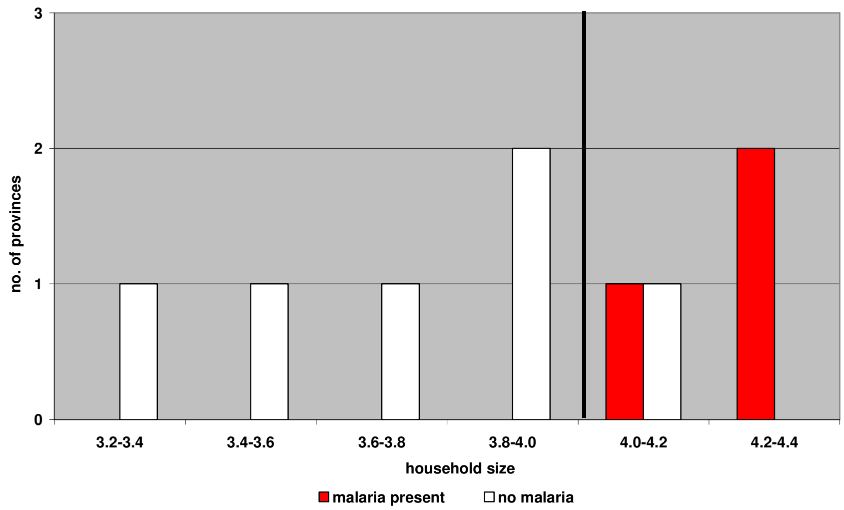

Figure A2.5. Malaria and household size in the provinces of South Africa

St Pierre & Miquelon

The island of Miquelon is reported to have had malaria in the past (O'Rourke 1959). There are, however, no reports of *Anopheles* species from St Pierre & Miquelon, so malaria probably only represented accidental imported cases. The interpretation here is that indigenous malaria never occurred in Miquelon. Neighbouring Newfoundland (Canada) is also reported to have had isolated cases of malaria in the 18th – 19th century (The London Encyclopaedia 1928). The potential vector, *Anopheles earlei*, has been reported from Newfoundland but the status of malaria is unclear (Wood et al. 1979).

Tajikistan

See comments for Russia.

Thailand

With an average household size of 3.9 Thailand could be close to an eradication of malaria. The country is, however, surrounded by the highly malarious countries of Myanmar, Laos, Cambodia and Malaysia, which all have a distinctly higher average household size of 4.8, 6.2, 5.2 and 4.5 respectively. Thailand is the primary destination of migration from these countries with nearly 1.3 million people entering the country in 2004 (WHO Mekong malaria programme 2008). Most of the malaria cases in Thailand are recorded close to the border region or in regions with foreign workers.

Trinidad & Tobago

Malaria was officially eradicated in 1965 (Chadee et al. 2000). In 1968 – 1998 *Plasmodium malariae* has repeatedly resurged in Trinidad and in 1966 in Tobago (Chadee et al. 1999). The cases are probably relapses because *P. malariae* can remain dormant in humans for a very long time.

Turkmenistan

See comments for Russia.

Ukraine

See comments for Russia.

United Kingdom

Historical malaria in England 1570 – 1810 has been studied by means of a decadal baptism/burial index (Dobson 1997). A corresponding dataset from 1720 – 1926 shows a long term slow decline until about 1760's when it became steeper (Hutchinson and Lindsay 2006). These data can be correlated with temperatures and rural population trends (Met Office). The correlations are as follows:

baptism / burial index and % rural population 1570 – 1810	+0·685***	$p<0.001$
baptism / burial index and summer mean temperature 1660 – 1810	-0.182	not significant
baptism / burial index and % rural population 1720 – 1925	+0.656***	$p<0.001$
baptism / burial index and summer mean temperature 1720 – 1925	+0.389°	$p<0.1$

Combining annual malaria data in 1850 – 1922 the malaria correlations with household size and summer mean temperatures are as follows [(Bruce-Chwatt and de Zulueta 1980, James 1924):

malaria and household size 1850 – 1922	+0.451***	$p<0.001$
malaria and summer mean temperature 1850 – 1922	+0.034	not significant

If we accept baptism / burial indices to represent malaria the correlation patterns are similar with corresponding correlation patterns in Finland in 1749 – 1960 (Hulden and Hulden 2009). Low frequency trends in malaria do not correlate with temperature trends. Declining household size is strongly correlating with decline of malaria.

Malaria occurred in the Orkneys and Shetland Islands in the 18th – 19th century and it disappeared in Scotland in 1919 (Bayliss 1985, Ritchie 1920, Ashworth 1927).

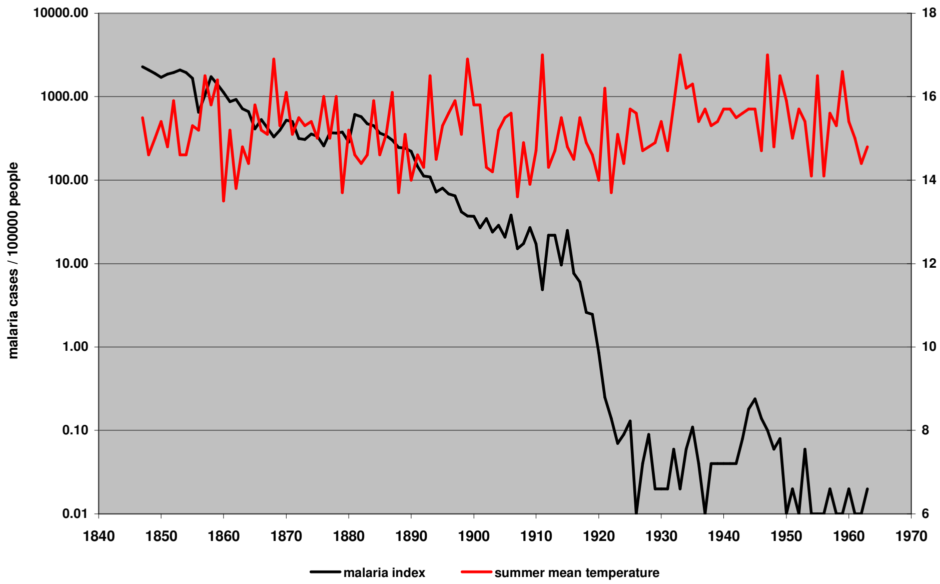

Figure A2.6. Malaria and summer mean temperature trends in United Kingdom in 1847-1963 (Met Office, James 1924).

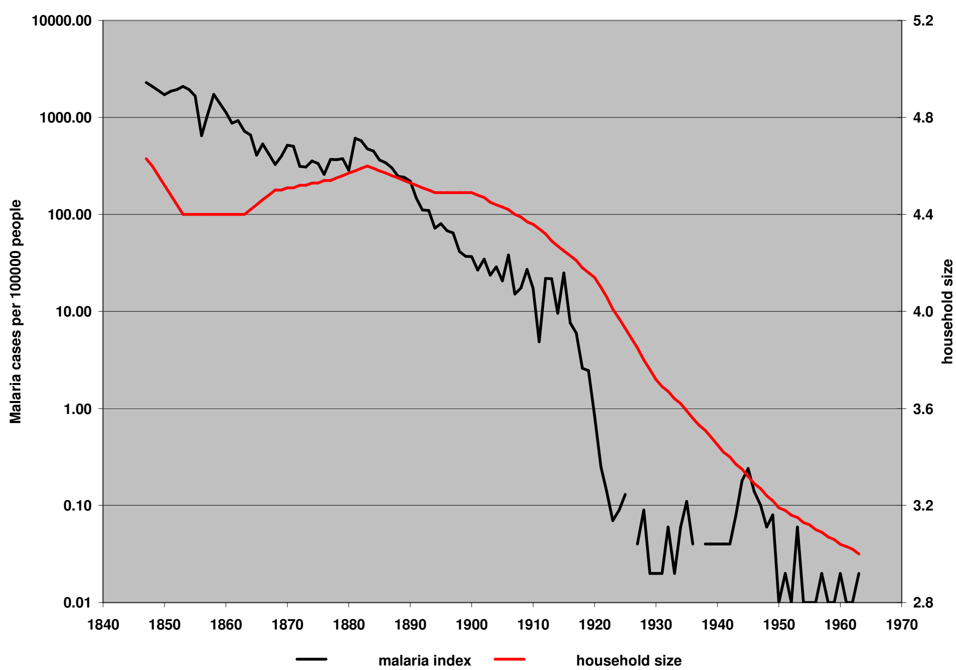

Figure A2.7. Malaria and household size trends in United Kingdom in 1847 – 1963 (Rothenbacher 2002, James 1924).

Uruguay

In the beginning of 20th century malaria was endemic in Uruguay (Doflein 1909, Röder 1930). Malaria was said to be rare and it was found along the Atlantic coast from Brazil to Argentina and in the central part along the river Rio Negro (Röder 1930). The disappearance of malaria is tentatively estimated to have been during the first decade of 20th century. Eight species of *Anopheles* are known from Uruguay including the potential vectors *A. albitarsis* and *A. oswaldoi*.

Uzbekistan

See comments for Russia.

Virgin Islands (UK)

There is only indirect information on malaria in British Virgin Islands. During the sudden outbreak of malaria in Barbados in 1927-1929 it was said that "... [Barbados] was the last fever-free British territory of the New World ..." indicating that British Virgin Islands belonged to the malaria islands at that time (Fonaroff 1966). In an enquiry by League of Nations ending in 1932 on quinine requirements of malarial countries in the world it was reported that British Virgin Islands in the 1920's treated annually on average 50 persons with totally 255 gram quinine League of Nations 1932). Malaria was probably eradicated after the WW II in the 1950's at the same time as in US Virgin Islands. The vector species *Anopheles albimanus* was reported from Tortola, but not mentioned by Faran in the revision of the *albimanus* group of *Anopheles* (Faran 1980, Charles and Senevet 1953).

Virgin Islands (US)

Malaria was prevalent in the US Virgin Islands (St. Croix, St. Thomas and St. John) in 1930's and 1940's (Virgin Islands Daily News 1948). It was eradicated in about 1950. *Anopheles albimanus* has been recorded on all the islands (Faran 1980). Information on malaria and vectors suggests an unstable occurrence of *Anopheles* species in the small Caribbean islands (see for a corresponding comment on Barbados). That may have affected the rapid eradication of malaria in most of the Caribbean in 1940's and 1950's.

Western Sahara

Because of the unsettled political situation malaria statistics are not available. Malaria was prevalent along the Atlantic coast of Western Sahara before 1946 (WHO 1995). In 2010 malaria was rare in Western Sahara (CDC 2010). Because the major part of the population in the Moroccan controlled part of the country lives in the capital region in the north, malaria cases is expected to be found there. There are no *Anopheles* species reported for Western Sahara but according to distribution maps of Moroccan species it is highly probable that *Anopheles sergentii* occurs in northern Western Sahara Trari et al. 2004).

A3. Global data on the use of DDT for malaria control

Country, malaria status, eradication year/last case	DDT use begin-ning	DDT use stop-ped	DDT total era in years	DDT years actual-ly used	DDT use, best estimate	
Afghanistan, endemic	1949	1979	31	31	1949-1979	Faulde et al. 2007, Kolaczinski et al. 2005
Albania, extinct, 1966	1947	1966	20	20	1947-1966	Bruce-Chwatt and de Zulueta 1980
Algeria, endemic	1964	1973	10	10	1964-1973	Hammadi et al. 2009
American Samoa, never endemic	0	0	0	0		
Andorra, never endemic	0	0	0	0		
Angola, endemic,	0	0	0	0		
Anguilla, never endemic	0	0	0	0		
Antigua et Barbuda, extinct , 1952	1950	1952	3	3	1950-1952	Uttley 1961
Argentina, endemic	1947	1997	51	51	1947-1997	Curo de Casa 1992, WHO-TRS 2001
Armenia, endemic , 1963	1949	1963	15	15	1949-1963	Lysenko and Kondraschin 1999
Aruba, never endemic	0	0	0	0		
Australia, extinct, 1962	1945	1962	18	18	1945-1962	Best 1973

Austria, extinct – spontaneous, 1946	0	0	0	0		
Azerbaijan, endemic , 1967	1949	1967	19	19	1949-1967	Lysenko and Kondraschin 1999
Bahamas, extinct, 1962	1952	1962	11	11	1952-1962	Rawlins et al. 2008, Hamoudi et Sachs 1999
Bahrain, extinct, 1979	1947	1967	21	21	1947-1967	UNEP-WHO 2003
Bangladesh, endemic	1950	1993	44	44	1950-1993	Rahman and Alam 1997, Pradeep et al. 2004, Quraishi et al. 1951
Barbados, never endemic, occasional	0	0	0	0		
Belarus , extinct, 1956	0	0	0	0		
Belgium, extinct – spontaneous, 1938	0	0	0	0		
Belize, endemic	1957	1999	43	43	1957-1999	Fernandez 2001, Hakre 2003
Benin, endemic	1950	1959	10	10	1950-1959	Yadouleton et al. 2010
Bermuda, never endemic	0	0	0	0		
Bhutan, endemic	1962	1995	34	34	1962-1995	Mittal et al. 2004, RBM Bhutan 2005
Bolivia, endemic	1956	1993	38	35	1956-1993	Russel 1957, PAHO 1980, WHO-DIS 2007
Bosnia et Herzegovina, extinct, 1959	1947	1963	17	17	1947-1963	Bruce-Chwatt and de Zulueta 1980

Botswana, endemic	1950	1997	48	48	1950-1997	Mabaso et al. 2004
Brazil, endemic	1947	1997	51	51	1947-1997	Guimaraes et al. 2007, Simmons et al. 1951
Brunei , extinct, 1970	1953	1966	14	14	1953-1966	Yassin 2011
Bulgaria, extinct, 1960	1947	1961	15	15	1947-1961	Bruce-Chwatt and de Zulueta 1980
Burkina Faso, endemic	1955	1964	10	10	1955-1964	Wright et al. 1972, Mouchet 1988, Coz et al. 1965
Burundi, endemic	1940	1960	21	21	1940-1960	Burundi 2006, proxy value
Cambodia, endemic	1953	1991	39	39	1953-1991	Cambodia 2004
Cameroon, endemic	1957	1961	5	5	1957-1961	Wright et al. 1972, Nwane et al. 2009
Canada, extinct, 1910	0	0	0	0		
Cape Verde, endemic	1948	1950	52	13	1948-1950,1990-1999	WHO 2007
Cayman Islands, extinct, 1950	0	0	0	0		
Central Africa, endemic	1946	1957	12	12	1946-1957	Thomson et Adloff 1960
Chad, endemic	1946	1957	12	12	1946-1957	Thomson et Adloff 1960
Chile, extinct, 1945	1944	1945	2	2	1944-1945	Simmons et al. 1951, Ulloa 1989
China, endemic	1955	2002	48	48	1955-2002	Devi et al. 2011, WHO-DIS China 2007,van den Berg 2011

Christmas Isl., never endemic	0	0	0	0		
Cocos (Keeling) Isl., never endemic	0	0	0	0		
Colombia, endemic	1956	1993	38	34	1956-1993	Rodriguez et al. 2011, PAHO 1980
Comoros, endemic	1956	1993	38	38	1956-1993	Kassim and Kumah 2006
Congo (Brazzaville), endemic	0	0	0	0		
Congo (Kinshasa) Dem Rep, endemic	1947	1953	7	7	1947-1953	WHO 1951, Lambrecht 1954
Cook Islands, never endemic	0	0	0	0		
Costa Rica, endemic	1955	1997	43	43	1955-1997	van Wendel de Joode et al. 2001
Cote d'Ivoire (Ivory C), endemic	0	0	0	0		
Croatia , extinct, 1952	1947	1963	17	17	1947-1963	Bruce-Chwatt and de Zulueta 1980
Cuba , extinct, 1967	1962	1967	6	6	1962-1967	Rivero et al. 2008, Guzman 1972
Cyprus, extinct, 1953	1946	1949	4	4	1946-1949	Shelley and Aziz 1949
Czech Republic, extinct – spontaneous, 1958	1946	1946	1	1	1946-1946	Sawyer 1947

Denmark, extinct – spontaneous, 1945	0	0	0	0		
Djibouti, endemic	1980	2002	23	23	1980-2002	UNEP-WHO 2003 illegal use, smuggled from Ethiopia
Dominica, extinct, 1959	1955	1959	5	5	1955-1959	Wright et al. 1972, Guzman 1972
Dominican Republic, endemic	1955	2009	55	16	1955-1968	Wright et al. 1972, Mekuria et al. 1990, van den Berg 2009
Ecuador, endemic	1959	2000	42	33	1959-2000	Roberts et 1997, van den Berg 2009, PAHO 1980
Egypt, endemic	1958	1996	39	39	1958-1996	Jaga and Dharmani 2003, Zahar 1974
El Salvador, endemic	1946	1973	28	26	1946-1973	El Salvador 2001, PAHO 1980
Equatorial Guinea, endemic	0	0	0	0		
Eritrea, endemic	1964	2009	46	46	1964-2009	GEF 2005, WHO-DIS Eritrea 2011
Estonia, extinct – spontaneous, 1952	0	0	0	0		
Ethiopia, endemic	1959	2009	51	51	1959-2009	GEF 2005, WHO-DIS Ethiopia 2011
Faeroe Isl., never endemic	0	0	0	0		
Falkland Isl., never endemic	0	0	0	0		
Fiji, never endemic	0	0	0	0		

Finland, extinct – spontaneous, 1954	0	0	0	0		
France, extinct – spontaneous, 1973	0	0	0	0		
French Guiana, endemic	1949	1990	42	13	1949-1960,1990	Claustre et al. 2001
French Polynesia, never endemic	0	0	0	0		
Gabon, endemic	1946	1957	12	12	1946-1957	Thomson and Adloff 1960
Gambia, endemic	0	0	0	0		
Georgia, endemic , 1970	1949	1970	22	22	1949-1970	Lysenko and Kondraschin 1999
Germany, extinct – spontaneous, 1941	0	0	0	0		
Ghana, endemic	1947	1969	23	23	1947-1969	Pampana 1948, Ghana 2007
Gibraltar, extinct – spontaneous, 1830	0	0	0	0		
Greece, extinct, 1972	1946	1959	14	14	1946-1959	Bruce-Chwatt and de Zulueta 1980
Greenland, never endemic	0	0	0	0		
Grenada, extinct, 1959	1957	1961	5	5	1957-1961	Ruderman 1961, Tikasingh et al. 1980
Guadeloupe, extinct, 1965	1951	1955	5	5	1951-1955	Sautet and Aldighieri 1954, Mouchet et al. 2008

Guam, never endemic	0	0	0	0		
Guatemala, endemic	1958	1979	22	22	1958-1979	CEC 2001
Guinea, endemic	0	0	0	0		
Guinea-Bissau, endemic	0	0	0	0		
Guyana, endemic	1945	2001	57	22	1945-1965,2001	Giglioli et al. 1967, WHO-DIS Guyana 2011
Haiti, endemic	1961	1979	19	19	1961-1979	Mason et al. 1965, Warren et al. 1985
Honduras, endemic	1951	1970	20	20	1951-1970	Mendez-Galvan et al. 2007, PAHO 1980
Hong Kong, extinct, 1988	1950	1988	39	39	1950-1988	Yip 2009, Devi et al. 2011
Hungary, extinct, 1956	1946	1952	7	7	1946-1952	Bruce-Chwatt and de Zulueta 1980
Iceland, never endemic	0	0	0	0		
India, endemic	1944	2000	57	54	1944,1948-2000	Sharma 2003
Indonesia, endemic	1951	1989	39	39	1951-1989	Dyson 2000, Barcus et al. 2002
Iran, endemic	1947	1973	27	27	1947-1973	Abivardi 2001, Franz 1960
Iraq, endemic	1952	1968	17	17	1952-1968	Abul-hab et al. 1986, Zahar 1974
Ireland, extinct – spontaneous, 1905	0	0	0	0		
Israel, extinct, 1963	1943	1963	21	21	1943-1963	Saliternik 1957, Farid 1954, Barkai and Saliternik 1967

Italy, extinct, 1964	1946	1951	6	6	1946-1951	Russel 1957, Bruce-Chwatt and de Zulueta 1980
Jamaica , extinct, 1958	1956	1958	3	3	1956-1958	Russel 1957, Gallup and Sachs 2001
Japan, extinct, 1961	1945	1960	16	16	1945-1960	Tanaka et al. 2009, Keiichi 2000
Jordan, extinct, 1997	1949	1967	19	19	1949-1967	Russel 1957, Zahar 1972
Kazakhstan, extinct, 1967	1949	1967	19	19	1949-1967	Lysenko and Kondraschin 1999
Kenya, endemic	1947	1986	40	40	1947-1986	Kibwana and Kiyiapi 2007
Kiribati, never endemic	0	0	0	0		
Korea North, endemic	1946	1973	28	28	1946-1973	Whang 1962, Pinyowiwat 2004
Korea South, endemic	1946	1969	24	24	1946-1969	Whang 1962, Ree 2000
Kosovo, extinct, 1959	1947	1959	13	13	1947-1959	Bruce-Chwatt and de Zulueta 1980
Kuwait, never endemic	0	0	0	0		
Kyrgyzstan, endemic , 1960	1949	1960	12	12	1949-1960	Lysenko and Kondraschin 1999
Laos, endemic	1953	1988	36	25	1953-1960,1970-1974,1977-1988	Laos 2010
Latvia, extinct – spontaneous, 1953	0	0	0	0		

Lebanon, extinct, 1963	1952	1963	12	12	1952-1963	Garrett-Jones and Gramiccia 1954, Bashour et al. 2004
Lesotho, never endemic	0	0	0	0		
Liberia, endemic	1945	1962	18	18	1945-1962	Kodiaga 2009, James 2011
Libya, extinct, 2000	1959	1971	13	13	1959-1971	Shalaby 1971
Liechtenstein , extinct – spontaneous, 1910	0	0	0	0		
Lithuania, extinct – spontaneous, 1956	0	0	0	0		
Luxembourg, extinct – spontaneous, 1850	0	0	0	0		
Macao, extinct, 1960	0	0	0	0		
Macedonia, extinct, 1964	1947	1963	17	17	1947-1963	Bruce-Chwatt and de Zulueta 1980
Madagascar, endemic	1949	2007	59	42	1949-1975,1993-2007	Mouchet et al. 1997, GEF 2005
Malawi, endemic	0	0	0	0		
Malaysia, endemic	1949	1996	48	48	1949-1996	Yap 1997, WHO Malaysia 2007, Simmons and Upholt 1951
Maldives , extinct, 1984	1965	1991	27	21	1965-1984,1991	Akiyama 1987, Moosa 2008

Mali, endemic	0	0	0	0		
Malta, extinct, 1905	0	0	0	0		
Marshall Islands, never endemic	0	0	0	0		
Martinique, extinct, 1960	1951	1955	5	5	1951-1955	Mouchet et al. 2008
Mauritania, endemic	0	0	0	0		
Mauritius , endemic , 2000	1949	1987	39	34	1949-1968	Safford et al. 1997, Tatarsky et al. 2011
Mayotte, endemic	1976	1989	14	14	1976-1989	Julvez et al. 1989
Mexico, endemic	1956	1999	44	42	1956-1999	Salazar-Garcia 2004, PAHO 1980
Micronesia, Fed. Stat., endemic	0	0	0	0		
Moldova, extinct – spontaneous, 1960	1949	1960	12	12	1949-1960	Lysenko and Kondraschin 1999
Monaco, never endemic, 1900	0	0	0	0		
Mongolia, never endemic	0	0	0	0		
Montenegro, extinct, 1959	1947	1959	13	13	1947-1959	Bruce-Chwatt and de Zulueta 1980
Montserrat, extinct, 1942	0	0	0	0		
Morocco, extinct, 2005	1965	2003	39	39	1965-2003	Adlaoui 2011, DDT-DIS 2005
Mozambique, endemic	1946	1993	48	45	1946-1956,1960-1993	Kloke 2009, DDT-DIS 2011

Myanmar, endemic	1952	2009	58	58	1952-2009	Dy 1954, SEARO Myanmar 2007, WHO-DIS Myanmar 2011
Namibia, endemic	1965	2009	45	45	1965-2009	Mabaso et al. 2004, DDT-DIS Namibia 2011
Nauru, never endemic	0	0	0	0		
Nepal, endemic	1952	1990	39	39	1952-1990	Mittal et al. 2004, IPEP 2006, Nepal 2010, Caryn et al. 2000
Netherlands, extinct, 1958	1950	1955	6	6	1950-1955	Simmons et al. 1951, Verhave 1987
Netherlands Antilles, extinct, 1940	0	0	0	0		
New Caledonia, never endemic	0	0	0	0		
New Zealand, never endemic	0	0	0	0		
Nicaragua, endemic	1959	2009	51	46	1959-2009	CEC 2001, WHO-DIS 2011, PAHO 1980
Niger, endemic	0	0	0	0		
Nigeria, endemic,	1949	2009	61	61	1949-1959,1960-2009	Wright et al. 1972, Africa 2009, Bruce-Chwatt 1951
Niue, never endemic	0	0	0	0		
Norfolk Island, never endemic	0	0	0	0		
Northern Mariana Isl., never endemic	0	0	0	0		

Norway, extinct – spontaneous, 1956	0	0	0	0		
Oman, endemic, (eradicated 2004)	1975	1990	16	16	1975-1990	WHO-EMRO 2002
Pakistan, endemic	1951	1982	32	32	1951-1982	Munir et al. 1995, Hemingway 1983
Palau, never endemic	0	0	0	0		
Palestine (Gaza+West Ba, extinct, 1966	1947	1952	6	6	1947-1952	Simmons et al. 1951:1947-, Farid 1954
Panama, endemic	1944	1986	43	28	1944-1986	Trapido 1952, PAHO 1980, PAHO 1988
Papua New Guinea, endemic	1946	1999	54	42	1946,1959-1999	Simmons et al. 1951, WHO-DIS PNG 2007, Keven et al. 2011
Paraguay, endemic	1958	1993	36	36	1958-1993	Lucas 2010, Roberts 1997
Peru, endemic	1949	1993	45	36	1949-1993	Pampana 1950, Roberts 1997
Philippines, endemic	1946	1992	47	47	1946-1992	Herald 1949, Carvalhoet 2010
Pitcairn, never endemic	0	0	0	0		
Poland, extinct – spontaneous, 1955	1949	1952	4	4	1949-1952	Bruce-Chwatt and de Zulueta 1980
Portugal, extinct, 1958	1948	1958	11	11	1948-1958	Bruce-Chwatt and de Zulueta 1980
Puerto Rico, extinct, 1959	1944	1955	12	12	1944-1955	Miranda and Vel 1997

Qatar, never endemic	0	0	0	0		
Reunion, extinct, 1979	1948	1979	32	32	1948-1979	Hamon and Dufour 1954, Tchen et al. 2006
Romania, extinct, 1962	1948	1962	15	15	1948-1962	Bruce-Chwatt and de Zulueta 1980
Russia, extinct, 1963	1949	1963	15	15	1949-1963	Lysenko and Kondraschin 1999
Rwanda, endemic	1947	1953	7	7	1947-1953	Mabaso et al. 2004 de Zulueta et al. 1961, Lambrecht 1954
Samoa, never endemic	0	0	0	0		
San Marino, never endemic	0	0	0	0		
Sao Tome et Principe, endemic	1980	1984	5	5	1980-1984	Tseng et al. 2008
Saudi Arabia, endemic	1947	1955	9	9	1947-1955	Daggy 1959
Senegal, endemic	1945	1950	6	6	1945-1950	Mabaso et al. 2004 Zulueta et al. 1961, Kartman 1946
Serbia, extinct, 1964	1947	1964	18	18	1947-1964	Bruce-Chwatt and de Zulueta 1980
Seychelles, never endemic	0	0	0	0		
Sierra Leone, endemic	1955	1955	1	1	1955-1955	Bruce-Chwatt 1956
Singapore, extinct, 1982	1964	1976	13	8	1964-1970, 1976	Chew 1968, Chan et al. 1971, Goh 1983

Slovakia, extinct – spontaneous, 1958	0	0	0	0		
Slovenia, extinct, 1964	1947	1963	17	17	1947-1963	Bruce-Chwatt and de Zulueta 1980
Solomon Islands, endemic	1962	1999	38	38	1962-1999	Over et al. 2004, Kere 1996, Slooff 1972
Somalia, endemic	1957	1980	24	15	1957-1960,1970-1980	Choumara 1961, Warsame et al. 1995
South Africa, endemic	1946	1996	51	51	1946-1996	Sharp et al. 2007
Spain, extinct – spontaneous, 1961	1947	1960	14	3	1947,1959,1960	Bettker 2008
Sri Lanka, endemic	1945	1975	31	26	1945-1955,1959-1965,1968-1975	Sri Lanka 2009
St Helena, never endemic	0	0	0	0		
St Kitts et Nevis, extinct, 1950	0	0	0	0		
St Lucia, extinct, 1959	1956	1959	4	4	1956-1959	Ruderman 1961, Jordan 1985
St Pierre et Miquelon, occasional	0	0	0	0		
St Vincent et Grenadines, extinct, 1952	0	0	0	0		
Sudan, endemic	1948	2002	55	55	1948-2002	Himeidan et al. 2011, Zahar 1974, Bruce-Chwatt 1984

Suriname, endemic	1955	1989	35	18	1955,1961-1962,1975-89	Hudson 1984, Voorham 1997, Rozendaal 1991
Swaziland, endemic	1947	2007	61	61	1947-2007	Mabaso et al. 2004
Sweden, extinct – spontaneous, 1933	0	0	0	0		
Switzerland, extinct – spontaneous, 1910	0	0	0	0		
Syria, endemic, 2004	1956	1968	13	13	1956-1968	Zahar 1974
Taiwan , extinct, 1973	1952	1973	22	22	1952-1973	Chang 2005
Tajikistan, endemic , 1963	1949	1963	15	15	1949-1963	Lysenko and Kondraschin 1999
Tanzania, endemic	1955	1997	43	43	1955-1997	Wright et al. 1972, AFRICA 2009
Thailand, endemic	1949	2000	52	52	1949-2000	Chareonviriyvaphap et al. 2000
Timor-Leste, endemic	1982	1991	10	10	1982-1991	WHO East Timor 1999
Togo, endemic	1950	1953	4	4	1950-1953	Mabaso et al. 2004 de Zulueta et al. 1961
Tokelau, never endemic	0	0	0	0		
Tonga, never endemic	0	0	0	0		
Trinidad et Tobago , extinct, 1962	1945	1961	17	17	1945-1961	Omardeen 1961, Yen et al. 1998, Matthews et al. 1970

Tunisia, extinct, 1979	1968	1972	5	5	1968-1972	Chahed et al. 2001
Turkey, endemic	1950	1983	34	34	1950-1983	Ayas 2007
Turkmenistan, endemic , 1960	1949	1960	12	12	1949-1960	Lysenko and Kondraschin 1999
Turks & Caicos Islands, never endemic	0	0	0	0		
Tuvalu, never endemic	0	0	0	0		
Uganda, endemic	1950	1963	14	6	1950,1959-1963	Coetzee 2006, Zulueta et al. 1961, Wilkinson 1951
Ukraine, extinct – spontaneous, 1956	1949	1956	8	8	1949-1956	Lysenko and Kondraschin 1999
United Arab Emirates, extinct, 2000	0	0	0	0		
United Kingdom, extinct – spontaneous, 1963	0	0	0	0		
United States, extinct, 1951	1947	1951	5	5	1947-1951	Humphreys 2001
Uruguay, extinct, 1900	0	0	0	0		
Uzbekistan, endemic , 1961	1949	1961	13	13	1949-1961	Lysenko and Kondraschin 1999
Vanuatu, endemic	1973	1982	10	10	1973-1982	WHO-WPR 2008
Venezuela, endemic	1945	1997	53	50	1945-1997	Simmons et al. 1951, WHO-TRS 2001

Viet Nam, endemic	1952	1995	44	44	1952-1995	Dy 1954, Nam et al. 2005
Virgin Isl. UK, extinct, 1950	0	0	0	0		
Virgin Isl. US, extinct, 1950	0	0	0	0		
Wallis & Futuna, never endemic	0	0	0	0		
Western Sahara, endemic	0	0	0	0		
Yemen, endemic	1970	2002	33	23	1970-1989,1998-2002	UNEP-WHO 2003, WHO-EMRO 2003a
Zambia, endemic	1946	1970	25	25	1946-1970	Utzinger 2002, Coetzee 2006
Zimbabwe, endemic	1948	1990	43	43	1948-1990	Mabaso et al. 2004, van den Berg 1995

A4. Malaria and dengue vector species

Table A4. Malaria vectors. Vector status of Anopheles species

Subgenus	Taxon	Vector status	
Anopheles	*algeriensis*	Secondary vector	Mari et al. 2011
Anopheles	*atroparvus*	Main vector	Manguin et al. 2008
Anopheles	*aztecus*	Local or occasional vector	Manguin et al. 2008
Anopheles	*bancroftii* s.s.	Main vector	Walter Reed 2011

Anopheles	*barbirostris*	Secondary vector	Manguin et al. 2008
Anopheles	*beklemishevi*	Secondary vector	Hulden & Hulden 2009
Anopheles	*calderoni*	Secondary vector	Wilkerson 1991
Anopheles	*campestris*	Main vector	Manguin et al. 2008
Anopheles	*claviger*	Secondary vector	Manguin et al. 2008
Anopheles	*coustani*	Secondary vector	Manguin et al. 2008
Anopheles	*donaldi*	Main vector	Manguin et al. 2008
Anopheles	*earlei*	Secondary vector	Bourke & Fergus 1959
Anopheles	*freeborni*	Main vector	Manguin et al. 2008
Anopheles	*gabaldoni*	Local or occasional vector	Manguin et al. 2008
Anopheles	*hermsi*	Secondary vector	Manguin et al. 2008
Anopheles	*hyrcanus*	Secondary vector	Manguin et al. 2008
Anopheles	*intermedius*	Secondary vector	Sinka et al. 2011
Anopheles	*kunmingensis*	Secondary vector	Manguin et al. 2008
Anopheles	*labranchiae*	Main vector	Manguin et al. 2008
Anopheles	*lesteri*	Main vector	Manguin et al. 2008
Anopheles	*letifer*	Main vector	Manguin et al. 2008
Anopheles	*maculipennis*	Secondary vector	Manguin et al. 2008
Anopheles	*mattogrossensis*	Secondary vector	Marrelli et al. 2005
Anopheles	*mediopunctatus*	Secondary vector	Marrelli et al. 2005
Anopheles	*melanoon*	Secondary vector	Manguin et al. 2008
Anopheles	*messeae*	Secondary vector	Manguin et al. 2008
Anopheles	*neomaculipalpis*	Secondary vector	Sinka et al. 2011
Anopheles	*obscurus*	Local or occasional vector	Stojanovich & Scott 1966
Anopheles	*paludis*	Secondary vector	Manguin et al. 2008

Anopheles	*persiensis*	Secondary vector	Sedaghat & Harbach 2005
Anopheles	*peryassui*	Secondary vector	Marrelli et al. 2005
Anopheles	*plumbeus*	Secondary vector	Manguin et al. 2008
Anopheles	*pseudopunctipennis* s.s.	Secondary vector	Manguin et al. 2008
Anopheles	*punctimacula*	Secondary vector	Walter Reed 2011
Anopheles	*quadrimaculatus*	Main vector	Manguin et al. 2008
Anopheles	*sacharovi*	Main vector	Manguin et al. 2008
Anopheles	*sicaulti*	Secondary vector	Manguin et al. 2008
Anopheles	*sinensis*	Main vector	Manguin et al. 2008
Anopheles	*vestitipennis*	Secondary vector	Sinka et al. 2011
Anopheles	*whartoni*	Secondary vector	Walter Reed 2011
Anopheles	*ziemanni*	Local or occasional vector	Kamau et al.2006
Cellia	*aconitus*	Main vector	Manguin et al. 2008
Cellia	*annularis*	Secondary vector	Manguin et al. 2008
Cellia	*arabiensis*	Main vector	Manguin et al. 2008
Cellia	*baimaii*	Main vector	Manguin et al. 2008
Cellia	*balabacensis*	Main vector	Manguin et al. 2008
Cellia	*brohieri*	Secondary vector	Gambia 2011
Cellia	*brunnipes*	Local or occasional vector	Manguin et al. 2008
Cellia	*bwambae*	Secondary vector	White 1985
Cellia	*carnevalei*	Secondary vector	Antonio-Nkondjio 2006
Cellia	*cinereus hispaniola*	Secondary vector	Becker et al. 2003
Cellia	*cracens*	Secondary vector	Manguin et al. 2008
Cellia	*culicifacies* spec A	Main vector	Manguin et al. 2008

Cellia	*culicifacies* spec C	Main vector	Manguin et al. 2008
Cellia	*culicifacies* spec D	Main vector	Manguin et al. 2008
Cellia	*culicifacies* spec E	Main vector	Manguin et al. 2008
Cellia	*dirus* s.s.	Main vector	Manguin et al. 2008
Cellia	*dthali*	Secondary vector	Manguin et al. 2008
Cellia	*farauti* s.s.	Main vector	Manguin et al. 2008
Cellia	*farauti* spec 4	Main vector	Henry-Halldin 2010
Cellia	*flavicosta*	Secondary vector	De Meillon 1951
Cellia	*flavirostris*	Main vector	Manguin et al. 2008
Cellia	*fluviatilis*	Main vector	Manguin et al. 2008
Cellia	*funestus*	Main vector	Manguin et al. 2008
Cellia	*gambiae*	Main vector	Manguin et al. 2008
Cellia	*hancocki*	Secondary vector	Antonio-Nkondjio 2006
Cellia	*hinesorum*	Secondary vector	Henry-Halldin 2010
Cellia	*karwari*	Secondary vector	Gideon 2007, Walter Reed 2011
Cellia	*koliensis*	Main vector	Manguin et al. 2008
Cellia	*latens*	Main vector	Vythilingham 2006
Cellia	*leucosphyrus*	Main vector	Manguin et al. 2008
Cellia	*leutens*	Main vector	WHO-SEARO 2007
Cellia	*litoralis*	Secondary vector	Manguin et al. 2008
Cellia	*longirostris*	Main vector	Cooper et al. 2006
Cellia	*ludlowae* s.s.	Main vector	Walter Reed Philippines
Cellia	*maculatus* s.s.	Main vector	Manguin et al. 2008
Cellia	*rampae*	Main vector	Manguin et al. 2008
Cellia	*maculipalpis*	Local or occasional vector	De Meilloni 1951

Cellia	*mangyanus*	Secondary vector	Manguin et al. 2008
Cellia	*marshallii*	Secondary vector	Antonio-Nkondjio 2006
Cellia	*mascarensis*	Secondary vector	Manguin et al. 2008
Cellia	*melas*	Secondary vector	Manguin et al. 2008
Cellia	*merus*	Secondary vector	Manguin et al. 2008
Cellia	*minimus*	Main vector	Manguin et al. 2008
Cellia	*moucheti*	Main vector	Manguin et al. 2008
Cellia	*nili*	Main vector	Manguin et al. 2008
Cellia	*nivipes* spec. A	Secondary vector	Manguin et al. 2008
Cellia	*nivipes* spec. B	Secondary vector	Manguin et al. 2008
Cellia	*ovengensis*	Secondary vector	Antonio-Nkondjio 2006
Cellia	*pattoni*	Secondary vector	Walter Reed 2011
Cellia	*pharoensis*	Main vector	Manguin et al. 2008
Cellia	*philippinensis*	Secondary vector	Manguin et al. 2008
Cellia	*pretoriensis*	Local or occasional vector	Stojanovich & Scott 1966
Cellia	*pseudowillmori*	Main vector	Manguin et al. 2008
Cellia	*pulcherrimus*	Secondary vector	Manguin et al. 2008
Cellia	*punctulatus*	Main vector	Manguin et al. 2008
Cellia	*rivulorum*	Secondary vector	Manguin et al. 2008
Cellia	*sawadwongporni*	Main vector	Manguin et al. 2008
Cellia	*scanloni*	Main vector	Manguin et al. 2008
Cellia	*sergentii* s.s.	Main vector	Manguin et al. 2008
Cellia	*smithii*	Local or occasional vector	Stojanovich & Scott 1966
Cellia	*stephensi*	Secondary vector	Manguin et al. 2008
Cellia	*subpictus*	Main vector	Manguin et al. 2008

Cellia	*sundaicus*	Main vector	Manguin et al. 2008
Cellia	*superpictus*	Main vector	Manguin et al. 2008
Cellia	*tessellatus* s.s.	Secondary vector	Manguin et al. 2008
Cellia	*torresiensis*	Main vector	Henry-Halldin 2010
Cellia	*vagus*	Local or occasional vector	Manguin et al. 2008
Cellia	*varuna*	Secondary vector	Manguin et al. 2008
Cellia	*wellcomei* s.s.	Secondary vector	Antonio-Nkondjio 2006
Cellia	*willmori*	Main vector	Manguin et al. 2008
Kertezia	*bellator*	Secondary vector	Manguin et al. 2008
Kertezia	*cruzii*	Secondary vector	Sinka et al. 2011
Kertezia	*homunculus*	Secondary vector	Manguin et al. 2008
Kertezia	*neivai*	Secondary vector	Manguin et al. 2008
Kertezia	*pholidotus*	Secondary vector	Montoya et al. 2011
Nysshorhynchus	*albimanus*	Main vector	Manguin et al. 2008
Nysshorhynchus	*albitarsis* s.s.	Main vector	Manguin et al. 2008
Nysshorhynchus	*aquasalis*	Main vector	Manguin et al. 2008
Nysshorhynchus	*benarrochi* s.s.	Secondary vector	Ruiz et al. 2005
Nysshorhynchus	*benarrochi* spec B	Secondary vector	Quinones at al. 2006
Nysshorhynchus	*braziliensis*	Secondary vector	Sinka et al.
Nysshorhynchus	*darlingi*	Main vector	Manguin et al. 2008
Nysshorhynchus	*deaneorum*	Secondary vector	Manguin et al. 2008
Nysshorhynchus	*benarrochi*	Secondary vector	Ruiz et al. 2005
Nysshorhynchus	*janconnae*	Main vector	Wilkerson & Sallum 2009
Nysshorhynchus	*marajoara*	Secondary vector	Walter Reed 2007
Nysshorhynchus	*nuneztovari*	Main vector	Manguin et al. 2008
Nysshorhynchus	*oswaldoi*	Secondary vector	Quinones et al. 2006

Nysshorhynchus	*rangeli*	Secondary vector	Quinones et al. 2006
Nysshorhynchus	*rondoni*	Secondary vector	Da Rocha et al. 2008
Nysshorhynchus	*strodei*	Secondary vector	Sinka et al. 2011
Nysshorhynchus	*triannulatus*	Secondary vector	Sinka et al. 2011

Table A5. Dengue vectors and their status

Aedes aegypti	main vector	cosmopolitan in warm regions	Brown et al. 2011
Aedes africanus	potential vector, on monkeys	Africa	Amarasinghe et al. 2011
Aedes albopictus	main vector	cosmopolitan in warm regions	Graz 2004
Aedes cooki	main vector	Pacific: Niue, Tonga	Guillaumot et al.2011
Aedes formosus	probable vector	Africa	Brown et al. 2011
Aedes furcifer	potential vector, on monkeys	Africa	Diallo et al. 2005
Aedes hebrideus	probable vector	Pacific: Vanuatu	Daggy 1944
Aedes hensilli	probable vector	Pacific: Federated States of Micronesia	Savage et al. 1998
Aedes horrescens	main vector	Pacific: Fiji	Prakash et al. 2001
Aedes kesseli	main vector	Pacific: Tonga	Guillaumot et al.2011
Aedes luteocephalus	, potential vector, on monkeys	Africa	Amarasinghe et al. 2011
Aedes mediovittatus	probable vector	Puerto Rico	Gubler 1985
Aedes niveus	potential vector, on monkeys	Peninsula Malaya	Wang et al. 2005
Aedes opok	potential vector, on monkeys	Africa	Wang et al. 2005

Aedes polynesiensis	main vector	Pacific: Futuna, Cook Islands, French Polynesia, Fiji	Prakash et al. 2001
Aedes pseudoscutellaris	main vector	Pacific: Fiji	Prakash et al. 2001
Aedes rotumae	main vector	Pacific: Fiji	Prakash et al. 2001
Aedes scutellaris	probable vector	human epidemic and transmission PNG	Moore et al. 2007
Aedes tabu	probable vector	Pacific Tonga	Guillaumot et al.2011
Aedes taylori	potential vector, on monkeys	monkeys Africa	Wang et al. 2005
Aedes tongae	main vector	Pacific: Tonga	Guillaumot et al.2011

Table A6. Dengue status and cases

Country	Dengue	Vector status	Average cases during 1990-2010 per 100000 people	Traveller aquired dengue from this country
Afghanistan	no dengue	vector present	0,00	
Albania	no dengue	vector present	0,00	
Algeria	no dengue	vector present	0,00	
American Samoa	dengue present	vector present	498,25	
Andorra	no dengue	no vector	0,00	
Angola	dengue present	vector present	0,00	Traveller
Anguilla	dengue present	vector present	73,74	
Antigua & Barbuda	dengue present	vector present	15,94	
Argentina	dengue present	vector present	1,63	
Armenia	no dengue	vector present	0,00	
Aruba	dengue present	vector present	72,38	
Australia	dengue present	vector present	1,80	

Austria	no dengue	no vector	0,00	
Azerbaijan	no dengue	vector present	0,00	
Bahamas	dengue present	vector present	24,66	
Bahrain	no dengue	vector present	0,00	
Bangladesh	dengue present	vector present	1,45	
Barbados	dengue present	vector present	146,99	
Belarus	no dengue	no vector	0,00	
Belgium	no dengue	vector present	0,00	
Belize	dengue present	vector present	26,41	
Benin	dengue present	vector present	0,00	Traveller
Bermuda	dengue present	vector present	3,70	
Bhutan	dengue present	vector present	82,60	
Bolivia	dengue present	vector present	28,14	
Bosnia & Herzegovina	no dengue	vector present	0,00	
Botswana	no dengue	vector present	0,00	
Brazil	dengue present	vector present	157,80	
Brunei	dengue present	vector present	15,42	
Bulgaria	no dengue	vector present	0,00	
Burkina Faso	dengue present	vector present	0,00	Traveller
Burundi	no dengue	vector present	0,00	
Cambodia	dengue present	vector present	76,69	
Cameroon	dengue present	vector present	1,68	Traveller
Canada	no dengue	no vector	0,00	
Cape Verde	dengue present	vector present	3712,64	
Cayman Islands	dengue present	vector present	5,31	
Central Africa	no dengue	vector present	0,00	

Chad	no dengue	vector present	0,00	
Chile	dengue present	vector present	0,90	
China	dengue present	vector present	0,23	
Christmas Isl.	no dengue	vector present	0,00	
Cocos (Keeling) Isl.	no dengue	vector present	0,00	
Colombia	dengue present	vector present	84,64	
Comoros	dengue present	vector present	4006,15	Traveller
Congo (Brazzaville)	no dengue	vector present	0,00	
Congo (Kinshasa) DemRep	dengue present	vector present	1,53	Traveller
Cook Islands	dengue present	vector present	2213,94	
Costa Rica	dengue present	vector present	298,92	
Cote d'Ivoire (Ivory C)	dengue present	vector present	0,15	Traveller
Croatia	imported cases	vector present	0,00	
Cuba	dengue present	vector present	22,70	
Cyprus	no dengue	no vector	0,00	
Czech Republic	no dengue	no vector	0,00	
Denmark	no dengue	no vector	0,00	
Djibouti	dengue present	vector present	547,99	Traveller
Dominica	dengue present	vector present	59,66	
Dominican Republic	dengue present	vector present	29,16	
Ecuador	dengue present	vector present	48,35	
Egypt	dengue present ?	vector present	0,00	
El Salvador	dengue present	vector present	102,28	

Equatorial Guinea	dengue present	vector present	0,00	Traveller
Eritrea	dengue present	vector present	0,00	
Estonia	no dengue	no vector	0,00	
Ethiopia	dengue present	vector present	0,00	Traveller
Faeroe Isl.	no dengue	no vector	0,00	
Falkland Isl.	no dengue	no vector	0,00	
Fiji	dengue present	vector present	259,11	
Finland	no dengue	no vector	0,00	
France	imported cases	vector present	0,00	
French Guiana	dengue present	vector present	1107,21	
French Polynesia	dengue present	vector present	329,79	
Gabon	dengue present	vector present	10,41	Traveller
Gambia	no dengue	vector present	0,00	
Georgia	no dengue	vector present	0,00	
Germany	no dengue	no vector	0,00	
Ghana	dengue present	vector present	0,00	Traveller
Gibraltar	no dengue	no vector	0,00	
Greece	no dengue	vector present	0,00	
Greenland	no dengue	no vector	0,00	
Grenada	dengue present	vector present	22,18	
Guadeloupe	dengue present	vector present	201,43	
Guam	dengue present	vector present	1,01	
Guatemala	dengue present	vector present	45,10	
Guinea	no dengue	vector present	0,00	
Guinea-Bissau	no dengue	vector present	0,00	
Guyana	dengue present	vector present	12,89	

Haiti	dengue present	vector present	0,00	
Honduras	dengue present	vector present	230,04	
Hong Kong	dengue present	vector present	0,58	
Hungary	no dengue	no vector	0,00	
Iceland	no dengue	no vector	0,00	
India	dengue present	vector present	0,68	
Indonesia	dengue present	vector present	28,97	
Iran	no dengue	vector present	0,00	
Iraq	no dengue	vector present	0,00	
Ireland	no dengue	no vector	0,00	
Israel	no dengue	vector present	0,00	
Italy	no dengue	vector present	0,00	
Jamaica	dengue present	vector present	12,84	
Japan	dengue present	vector present	0,05	
Jordan	no dengue	vector present	0,00	
Kazakhstan	no dengue	no vector	0,00	
Kenya	dengue present	vector present	0,00	Traveller
Kiribati	dengue present	vector present	743,75	
Korea North	no dengue	vector present	0,00	
Korea South	dengue present	vector present	0,09	
Kosovo	no dengue	no vector	0,00	
Kuwait	no dengue	vector present	0,00	
Kyrgyzstan	no dengue	no vector	0,00	
Laos	dengue present	vector present	106,98	
Latvia	no dengue	no vector	0,00	
Lebanon	no dengue	vector present	0,00	

Lesotho	no dengue	vector present	0,00	
Liberia	no dengue	vector present	0,00	
Libya	no dengue	vector present	0,00	
Liechtenstein	no dengue	no vector	0,00	
Lithuania	no dengue	no vector	0,00	
Luxembourg	no dengue	no vector	0,00	
Macao	dengue present	vector present	41,70	
Macedonia	imported cases	vector present	1,88	
Madagascar	dengue present	vector present	6,87	Traveller
Malawi	no dengue	vector present	0,00	
Malaysia	dengue present	vector present	101,06	
Maldives	dengue present	vector present	276,09	
Mali	dengue present	vector present	0,00	Traveller
Malta	no dengue	no vector	0,00	
Marshall Islands	dengue present	vector present	107,69	
Martinique	dengue present	vector present	400,69	
Mauritania	no dengue	vector present	0,00	
Mauritius	dengue present	vector present	16,86	
Mayotte	dengue present	vector present	107,32	?
Mexico	dengue present	vector present	20,02	
Micronesia, Fed. Stat.	dengue present	vector present	156,70	
Moldova	no dengue	no vector	0,00	
Monaco	no dengue	vector present	0,00	
Mongolia	no dengue	no vector	0,00	
Montenegro	no dengue	vector present	0,00	
Montserrat	dengue present	vector present	267,50	

Morocco	no dengue	vector present	0,00	
Mozambique	dengue present	vector present	0,00	Traveller
Myanmar	dengue present	vector present	20,87	
Namibia	dengue present	vector present	0,00	Traveller
Nauru	dengue present	vector present	1175,00	
Nepal	dengue present	vector present	0,34	
Netherlands	no dengue	vector present	0,00	
Netherlands Antilles	dengue present	vector present	43,31	
New Caledonia	dengue present	vector present	618,14	
New Zealand	imported cases	no vector	0,92	
Nicaragua	dengue present	vector present	115,01	
Niger	no dengue	vector present	0,00	
Nigeria	dengue present	vector present	0,00	Traveller
Niue	dengue present	vector present	150,00	
Norfolk Island	no dengue	no vector	0,00	
Northern Mariana Isl.	no dengue	vector present	0,00	
Norway	no dengue	no vector	0,00	
Oman	no dengue	vector present	0,00	
Pakistan	dengue present	vector present	1,70	
Palau	dengue present	vector present	1622,11	
Palestine (Gaza+West Ba	no dengue	no vector	0,00	
Panama	dengue present	vector present	63,67	
Papua New Guinea	dengue present	vector present	4,67	
Paraguay	dengue present	vector present	116,78	

Peru	dengue present	vector present	21,56	
Philippines	dengue present	vector present	32,90	
Pitcairn	no dengue	no vector	0,00	
Poland	no dengue	no vector	0,00	
Portugal	no dengue	vector present	0,00	
Puerto Rico	dengue present	vector present	196,60	
Qatar	no dengue	vector present	0,00	
Reunion	dengue present	vector present	690,61	
Romania	no dengue	vector present	0,00	
Russia	no dengue	no vector	0,00	
Rwanda	dengue present	vector present	0,00	Traveller
Samoa	dengue present	vector present	104,48	
San Marino	no dengue	vector present	0,00	
Sao Tome & Principe	no dengue	vector present	0,00	
Saudi Arabia	dengue present	vector present	0,47	
Senegal	dengue present	vector present	0,53	Traveller
Serbia	no dengue	no vector	0,00	
Seychelles	dengue present	vector present	54,32	
Sierra Leone	no dengue	vector present	0,00	
Singapore	dengue present	vector present	107,44	
Slovakia	no dengue	no vector	0,00	
Slovenia	no dengue	vector present	0,00	
Solomon Islands	dengue present	vector present	0,72	
Somalia	dengue present	vector present	0,00	Traveller
South Africa	dengue present	vector present	0,00	Traveller
Spain	no dengue	vector present	0,00	

Sri Lanka	dengue present	vector present	35,77	
St Helena	no dengue	no vector	0,00	
St Kitts & Nevis	dengue present	vector present	36,96	
St Lucia	dengue present	vector present	26,88	
St Pierre & Miquelon	no dengue	no vector	0,00	
St Vincent & Grenadines	dengue present	vector present	31,76	
Sudan	dengue present	vector present	0,00	
Suriname	dengue present	vector present	121,72	
Swaziland	no dengue	vector present	0,00	
Sweden	no dengue	no vector	0,00	
Switzerland	no dengue	vector present	0,00	
Syria	no dengue	vector present	0,00	
Taiwan	dengue present	vector present	7,39	
Tajikistan	no dengue	no vector	0,00	
Tanzania	dengue present	vector present	0,12	Traveller
Thailand	dengue present	vector present	105,81	
Timor-Leste	dengue present	vector present	52,74	
Togo	dengue present	vector present	0,00	Traveller
Tokelau	dengue present	vector present	200,00	
Tonga	dengue present	vector present	180,00	
Trinidad & Tobago	dengue present	vector present	108,05	
Tunisia	no dengue	vector present	0,00	
Turkey	no dengue	vector present	0,00	
Turkmenistan	no dengue	no vector	0,00	

Turks & Caicos Islands	dengue present	vector present	7,02	
Tuvalu	dengue present	vector present	8110,00	
Uganda	dengue present	vector present	0,00	Traveller
Ukraine	no dengue	no vector	0,00	
United Arab Emirates	no dengue	vector present	0,00	
United Kingdom	no dengue	vector present	0,00	
United States	imported cases	vector present	0,02	
Uruguay	dengue present	vector present	0,03	Traveller
Uzbekistan	no dengue	no vector	0,00	
Vanuatu	dengue present	vector present	37,78	
Venezuela	dengue present	vector present	141,06	
Viet Nam	dengue present	vector present	90,46	
Virgin Isl. UK	dengue present	vector present	33,33	
Virgin Isl. US	dengue present	vector present	118,64	
Wallis & Futuna	dengue present	vector present	3865,33	
Western Sahara	no dengue	no vector	0,00	
Yemen	dengue present	vector present	2,04	
Zambia	dengue present	vector present	0,00	Traveller
Zimbabwe	no dengue	vector present	0,00	

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