

MALARIA INCIDENCE ESTIMATES AT COUNTRY LEVEL FOR THE YEAR 2004

- ANNEXES & BACKGROUND PAPERS -

Draft October 8 2004, not for citation or general distribution

Eline Korenromp, Arantxa Roca-Feltrer and Ilona Carneiro,
for the RBM Monitoring and Evaluation Reference Group & MERG Task Force on Malaria Morbidity

World Health Organization, Roll Back Malaria,
Avenue Appia 20, CH-1211 Geneva 27, Switzerland.

&

Disease Control & Vector Biology Unit
Department of Infectious & Tropical Disease
London School of Hygiene & Tropical Medicine

Annexes

1. Estimation of basic malaria incidence rates outside of Africa
2. ITN and IRS coverage and country risk areas
3. Country endemicity distributions: comparison between global map and countries' or region's own estimate, for non-African countries.
4. Correlation of incidence estimates for AFRO with HIS outcomes.

Background papers

- I. CHERG estimates of malaria morbidity in African under-fives. Report on malaria incidence in African under-fives (Ilona Carneiro, Arantxa Roca-Feltrer and Joanna Schellenberg, London School of Hygiene and Tropical Medicine).
- II. Determination of country populations at malaria risk of different endemicities - report on agreement to perform work (APW) for WHO/Roll Back Malaria (Simon Hay, Carlos Guerra and Robert Snow, Oxford University, Dept. of Zoology).

ANNEX 1. ESTIMATION OF BASIC MALARIA INCIDENCE RATES OUTSIDE OF AFRICA

Regression analysis of incidence research studies

A literature review of community-based longitudinal studies of the incidence of malaria episodes was undertaken to identify relevant data in any age group. The inclusion criteria were that studies: 1) were population-based longitudinal studies of the incidence of symptomatic malaria; 2) detected malaria episodes from active case detection (ACD); 3) had a focus on symptomatic malaria (defined as fever symptoms + parasitaemia) and 4) did not overlap in time or place with another study in the analysis. For trials of malaria control by ITN or IRS, only results from the control groups were included; for trials of other malaria interventions, all study groups were included.

Information abstracted on the studies and study populations included location (longitude and latitude), malaria endemicity, type of residence (rural/urban), study period and age range under surveillance. Investigators were contacted when articles were difficult to abstract or had missing information. The malaria endemicity of research locations was determined by plotting the latitude and longitude of sites on the global endemicity map we used for defining populations at risk (¹ and Background paper II). For three studies for which this could not be done, the endemicity category as described by study authors was used instead. Furthermore, to account for the fact that studies probably oversampled focal areas of high malaria, which would not be reflected in the global endemicity map due to its limited geographical resolution, studies which themselves described a higher endemicity than the global map were classified according to their own definition. Using this algorithm, 4 studies were re-classified from hypoendemic to mesoendemic and 6 studies from mesoendemic to hyperendemic (Table A1).

Linear regression modelling was used to estimate the malaria incidence rate as a function of population characteristics and adjusting for differences in study design, using STATA 8 (StataCorp. 2003. Stata Statistical Software: Release 7.0. College Station, TX: Stata Corporation). Analyses were clustered by country, to adjust standard errors for intra-country correlation due to non-independence of population characteristics within the same country. All factors found to be significant at the $p < 0.1$ in univariate analysis were considered for entry into a multivariate model. To be included in the final model, variables needed to have a significant association with malaria incidence ($p\text{-value} < 0.10$). All studies were weighted equally.

Forty two studies were eligible (Table A1). They reported rates from 44 different non-intervention sub-populations, since two studies reported incidence rates each for two different study sub-populations. Across the studies, incidence rates for *falciparum* and *vivax* malaria combined ranged from 0.003 to 1.9 episodes per person per year (pppa). The median proportion of cases due to *P. falciparum* was 52% (IQR: 41%-58%).

In univariate analysis, four variables were found to have a significant effect: endemicity, age, type of residence (urban or rural), and geographical region (Table A2).

Most studies were classified as meso-endemic ($n=14$) or hyper-endemic ($n=26$). No studies were available from hypo-endemic areas. Four studies from Papua New Guinea were classified as holoendemic, and these were all on children in rural areas. Since the regression model was meant to subsequently be applied to national populations of all ages and covering both urban and rural areas, we therefore confined it to meso-endemic and hyper-endemic areas; an alternative approach was taken for holo-endemic areas (see below). Pooled across studies, malaria incidence was 0.43 pppa (95% CI: 0.06-0.80) in meso-endemic areas and 0.58 pppa (95% CI: 0.21-0.96) in hyper-endemic areas.

Two of the 40 study outcomes for meso-endemic and hyper-endemic areas were for urban residences, and in these malaria incidence was lower than in rural residences, at 0.071 pppa against 0.55 pppa (95% CI:

0.29-0.82), respectively. Both urban studies had been carried out in India and therefore no CIs could be obtained. Although malaria epidemiology in India is probably not representative of the rest of the world because of the presence of a unique, well-adapted urban vector (*Anopheles stephensi*), in a subanalysis confined to Indian urban and rural studies incidence was still lower in urban than in rural areas. Therefore urbanicity was considered for the multivariate model.

Since studies used a variety of age ranges (children under-five, under-fifteen, adults, all ages combined...) but not always reported incidence rates disaggregated by age group, the effect of age was first analyzed in a subset of studies. Ten studies (8 articles) provided an age breakdown between 0-4 years, 5-14 years, and ≥ 15 years (2, 3, 4, 5, 6, 7, 8 and Da Silva Nunes *et al.*, p.c.). Across these, the incidence rate was slightly higher, at 0.56 pppa (95%CI: 0.24-0.89) for under-fives compared to children aged 5-14 years (0.55 pppa, 95%CI: 0.27-0.84) and adults (0.48 pppa, 95%CI: 0.16-0.80), p for trend = 0.091 (Table A2). The age pattern was not significantly different between the six studies from meso-endemic areas and the four studies from hyper-endemic areas. Among the total set of studies on sub-age groups and in cruder classifications, 10 reported on children (<15 years old) and 30 on all age groups combined. In univariate analysis, incidence rates were significantly higher in children (0.96 pppa, 95%CI: 0.59-1.32) compared to all ages 0.39 pppa (95%CI: 0.26-0.52). Therefore age was considered in the multivariate analysis.

Other variables studied, study period (categorized as the mid-year of the study, up to and including 1990 versus after 1990), whether the study was year-round or not (relevant in case of seasonal malaria), and the frequency of (active) case detection were not significant, and incidence did not significantly vary with the proportion of cases due to *P. falciparum* (not shown). World continent was considered as an additional variable, but appeared to be auto-correlated with endemicity. Therefore, continent was not included in the multivariate model.

For the multivariate model were thus considered, endemicity, age group and type of residence. Since we *a priori* expected the age pattern in malaria incidence to vary by endemicity, the interaction between these variables was also considered. The final model included type of residence and the interaction between age and endemicity, and it explained 38% of the variation in incidence rates between non-African settings not subject to malaria prevention by IRS or ITN (Table A3 and Figure A1). According to the model, incidence was higher in children than at older age, higher in rural than in urban areas, and in rural areas higher at hyper-endemic risk than at meso-endemic risk.

Table A2. Univariate least squares linear regressions on determinants of malaria incidence in community-based longitudinal studies from outside Africa at meso-endemic and hyper-endemic risk. Results refer to the absence of malaria control through ITN or IRS.

Variable	Categories	# studies	Incidence rate pppa		P-value	Considered for multivariate model
			Observed median [IQR]	Univariate estimate [95% CI]		
Geographical region	Latin America	12	0.38 [0.27-0.95]	0.54 [0.29-0.79]	<0.001	No, because of probable auto-correlation with endemicity, which we give priority as an <i>a priori</i> plausible determinant of malaria incidence.
	Indian sub-continent	14	0.24 [0.05-0.60]	0.31 [0.12-0.49]		
	South East Asia	11	0.40 [0.04-0.95]	0.52 [0.20-0.83]		
	Western Pacific	3	1.47 [1.40-1.90] [#]	1.59*		
Endemicity	Hyper-endemic	26	0.40 [0.24-0.85]	0.58 [0.21-0.79]	0.496	Yes, because significant if including also holo-endemic areas, and <i>a priori</i> considered to be a
	Meso-endemic	14	0.31 [0.05-0.87]	0.43 [0.060.80]		

Variable	Categories	# studies	Incidence rate pppa		P-value	Considered for multivariate model
			Observed median [IQR]	Univariate estimate [95% CI]		
						determinant of malaria incidence
Study Year	<1990	5	0.05 [0.014-0.67]	0.20 [0.02-0.39]	0.118	No, because not significant
	≥1990	35	0.40 [0.27-0.85]	0.58 [0.24-0.91]		
Study year-round or not	(Multiple of) 12 months	28	0.34 [0.19-0.82]	0.50 [0.19-0.82]	0.519	No, because not significant
	Not (multiple of) 12 months	12	0.61 [0.13-0.93]	0.59 [0.29-0.89]		
Type of residence	Rural	38	0.40 [0.27-0.82]	0.55 [0.29-0.82]	0.002	Yes
	Urban	2	0.07 [0.01-0.13] [#]	0.071**		
Type of (active) surveillance ⁺	Monthly or less frequent	5	0.27 [0.04-0.62]	0.27 [0.11-0.43]	0.366	No, because not significant
	Fortnightly	22	0.40 [0.21-0.90]	0.60 [0.19-1.00]		
	Weekly or more frequent	11	0.35 [0.05-0.97]	0.45 [0.15-0.75]		
Age (whole dataset)	Children (<15 years old)	10	0.96 [0.34-1.45]	0.96 [0.59-1.32]	0.043	
	All ages	30	0.28 [0.13-0.58]	0.39 [0.26-0.52]		
Age (sub-analysis of 9 studies)	0-4 years old	10 [£]	0.57 [0.07-1.04]	0.56 [0.24-0.89]	0.091	Yes, because significant across total set of studies.
	5-14 years old	10 [£]	0.47 [0.-0.95]	0.55 [0.27-0.84]		
	15+ years old	10 [£]	0.30 [0.08-0.85]	0.48 [0.16-0.80]		

[£] All 10 studies contributed to all groups.

[#] Lower and upper confidence limits were minimum and maximum values of Western Pacific studies.

*All **?** studies in **holoendemic** areas were carried out in Papua New Guinea and therefore no appropriate CIs could be obtained.

** Both urban studies were carried out in India and therefore no appropriate CIs could be obtained.

⁺ The frequency of surveillance was unknown for 2 studies

IQR=interquartile range, SE=standard error, CI= confidence interval.

Table A3. Multivariate least-squares linear regression of determinants of all-age malaria incidence in non-African populations at meso-endemic and hyper-endemic risk. Results refer to the absence of malaria control through ITN or IRS.

Parameter		Coefficient	SE	p-value
Intercept	Children, rural, hyper-endemic	1.09	0.291	0.004
Type of residence	Urban	-0.347	0.088	0.003
Endemicity	Meso-endemic	-0.651	0.440	0.17
Interaction age * endemicity	All ages * hyper-endemic	-0.712	0.282	0.03
	All ages * meso-endemic	0.023	0.333	0.95

R²=0.38, 40 study outcomes

SE=standard error of the coefficient. N.a.=not available, R²=proportion of explained variation.

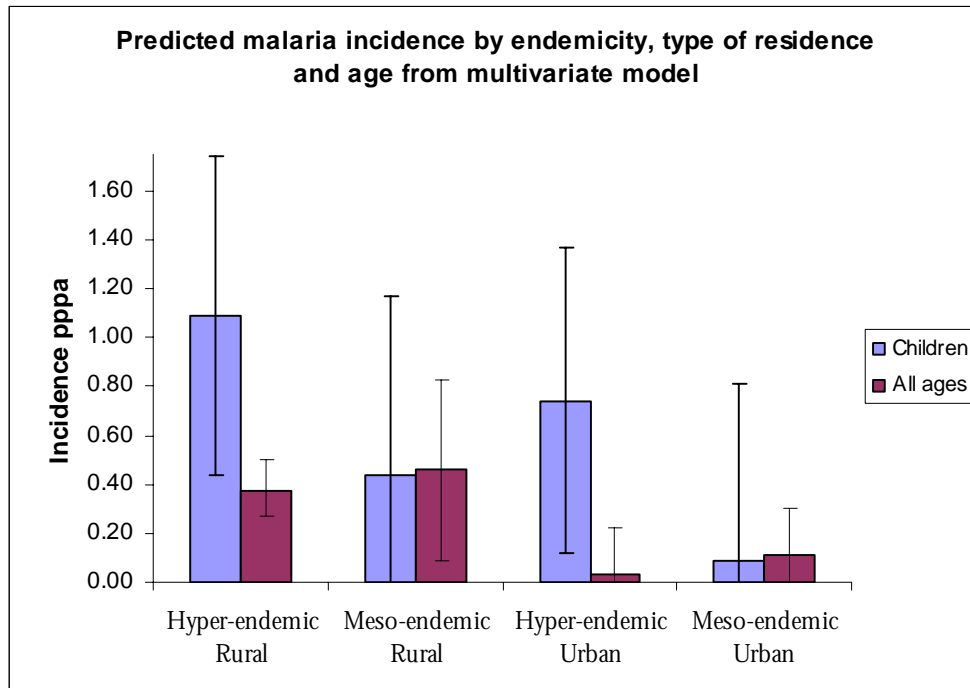


Figure A1. Estimated malaria incidence outside of Africa in the absence of ITN or IRS impact, by endemicity and study period. Error bars denote the 95% confidence interval.

Estimated rate for holo-endemic areas

The average malaria incidence rate across four studies on children in holo-endemic Papua New Guinea was 0.96 pppa; no data were available on older age groups. Since this rate was very similar to the estimate for children under-five in high-endemic rural middle Africa (1.04 pppa, see above), we applied the middle African estimates to holo-endemic areas outside of Africa, i.e. 1.04 pppa for children under-5, 0.587 pppa for 5-14 years old 0.107 pppa for ≥ 15 years old.

Estimated rate for meso- and hyper-endemic areas

Comparing the regression model for meso- and hyper-endemic areas outside Africa with the Africa-based result for holo-endemic areas, paradoxically, the incidence rate estimates were higher for meso- and hyper-endemic rural areas (0.46 pppa and 0.38 pppa, respectively, for all ages combined) than for holo-endemic rural areas (0.36-0.38 pppa, as an age aggregate). Further, the age-specific rates for hyper-endemic urban areas were internally inconsistent: at a rate of 0.74 pppa in children aged 0-4 years, for non-African populations with around 7% in the 0-4 years age group, the all-age rate would be at least 0.05 pppa, not the estimated 0.03 pppa, and still higher if 'children' in the regression referred to all children up to 14 years.

These improbable results may have several reasons. First, studies included in the regression model probably oversampled areas of high malaria incidence and/or endemicity, even within given endemicity categories. An indication for relatively high intensity malaria in the research studies is found in the high proportion of malaria cases in these studies that was due to *P. falciparum* - a median of 52% (Table A1), against a median of 36% of cases notified nationally in non-AFRO countries (Table 1). This is not surprising in these studies of 'active case detection', since active case detection is typically done to trace and treat missing cases that have not reached the health system, focusing on the areas where the largest

proportion of such cases are expected to be found. This is quite the opposite of a randomly sampled survey or geographically comprehensive surveillance that would be representative of a given area. Second, some of the included studies in areas of seasonal malaria had covered the malaria season but not the non-malarious months. Since the effect of study period not being a multiple of 12 months was not significant in univariate analysis (Table A2), this variable was not included in the multivariate model but it may nevertheless have inflated the incidence estimate, by up to 1.8-fold. Third, active case detection, by counting all cases of current or recent fever with concurrent parasitemia as malaria, by definition overestimates true malaria in areas where some fevers are of non-malarial origin or where asymptomatic parasitemia occurs.

These considerations, and the inconsistency between child and all-age estimates for hyper-endemic urban areas, made it inappropriate to apply the regression-based incidence estimates directly in extrapolation to countries. Instead, we started from the estimate for children in rural hyper-endemic areas (1.09 pppa). Assuming that this rate held for children 0-4 years (although studies on children in rural hyper-endemic areas were mostly for children aged up to 9 years), by applying the African pattern of decline in incidence with age we then derived rates for age groups 5-14 years and ≥ 15 years, of 0.64 pppa and 0.12 pppa, respectively. These age-specific rates yielded an all-age rate for rural hyper-endemic areas of 0.40, which was similar to that for holo-endemic areas in Africa and the Western Pacific. For meso-endemic rural areas, a rate of 0.45 pppa (average between the predicted 0.44 pppa for children and 0.46 pppa for all-ages) was taken for all children under-fifteen. Although the model did not reveal an age decline in meso-endemic areas, we applied a somewhat lower rate (0.30 pppa) for over-fifteens, since a moderate age decline seemed plausible and prevented the all-age rate to be greater for meso-endemic areas than for hyper-endemic areas, which was deemed implausible.

Applying the rate difference from the model of 0.35 pppa less malaria in urban compared to rural areas to these numbers would give negative incidence rates for some categories. This is probably due to the limitation of the regression model to predict rate *differences* instead of rate *ratios*. From the model, the average rate ratio urban-to-rural was around 0.3 (meso-endemic areas $0.10/0.45 \approx 0.22$, children at hyper-endemic risk $0.75/1.09 \approx 0.68$; all ages at hyper-endemic risk $0.03/0.38 \approx 0.08$), and we applied this ratio to the estimated age- and endemicity specific rates described above. This ratio is in line with the urban-rural ratio in self-reported malaria in the 1998-9 DHS survey in India (all ages combined, 0.43 per person per 3 months rurally and 0.22 per person per 3 months in urban areas)⁹.

Estimated rate for hypo-endemic areas

Since no community-based longitudinal studies were available on malaria incidence in hypo-endemic areas, instead we applied an existing estimate for areas at epidemic risk within middle Africa, of 0.061 pppa, for all age groups¹⁰. This rate was based on a documented incidence rate of around 0.976 pppa at all ages during epidemics, which were assumed to last 3 months and to occur on average every 4 years.

ANNEX 2. ITN AND IRS COVERAGE IN COUNTRIES AND COUNTRY RISK AREAS

ITN coverage

For 41 countries, coverage with insecticide-treated mosquito nets (ITN) coverage was known from national DHS or MICS household surveys^{11, 12}, in the definition of the proportion of under-5s that had slept under an ITN during the night preceding the survey. For the WPRO countries Cambodia, Philippines, Republic of Korea and Vanuatu, ITN coverage had been estimated by WPRO, as the proportion of the population at risk that was covered by an ITN distribution programme. In both cases, ITNs were defined as mosquito nets that had ever been treated with insecticide.

National-level coverage estimates potentially underestimate the effective coverage among population at malaria risk in countries where only a small part of the population is at malaria risk. Ideally, ITN coverage and malaria transmission risk are therefore co-analyzed at a subnational level, but the national surveys cannot be validly disaggregated to a low-enough (sub-province) level. Since malaria and mosquito nuisance, which is likely to geographically cluster with exposure to malaria, are the main reasons for ITN usage, we assumed that all ITNs were used in population at risk, and national-level coverage estimates were adjusted by dividing them by the proportion of the national population at malaria risk.

This adjustment made little difference to ITN coverage for the majority of countries, since most countries with survey-based ITN coverage estimates had over 90% of the population at malaria risk and very low ITN coverage anyway. Only in Azerbaijan, Suriname and Guyana, which had comparatively small parts of their populations at risk and a considerable ITN coverage, the conversion resulted in a markedly increased coverage estimate (Table A5).

Table A5. National ITN coverage estimates and their adjustment to reflect coverage in populations at malaria risk (shown, brevity, only for countries with less than 90% of the population at risk).

<i>Region</i>	<i>Country</i>	<i>Population at risk (see Background paper II)</i>	<i>Survey on ITN coverage</i>	<i>National ITN coverage</i>	<i>ITN coverage in population at risk, assuming all ITN usage is in households at risk</i>
AFRO	Rwanda	67%	DHS 2000	4.3%	6.5%
AFRO	Kenya	78%	MICS 2000	2.9%	3.7%
AFRO	Burundi	85%	MICS 2000	1.3%	1.5%
EURO	Azerbaijan	18%	MICS 2000	1.4%	7.8%
EURO	Tajikistan	17%	MICS 2000	1.4%	8.3%
PAHO	Suriname	7%	MICS 2000	2.7%	39%
PAHO	Guatemala	51%	MICS 1999	1.2%	2.3%
PAHO	Colombia	30%	DHS 2000	2.8%	9.3%
PAHO	Guyana	37%	MICS 2000	8.1%	22%
SEARO	Indonesia	71%	MICS 2000	0.1%	0.1%

Note: Southern African countries are not included here because the incidence estimation does for these countries not rely on ITN coverage.

IRS coverage

Comparatively little quantitative data were available on IRS coverage. For countries in AFRO and EMRO, IRS coverage could be estimated based on numbers of households sprayed. We multiplied these with the average number of persons per household (available from DHS surveys) to obtain the total

population under spray. Assuming that IRS programmes target at-risk areas, this was then divided by the proportion of the population at risk (Table A6).

Table A6. Country-level estimates of the coverage with indoor residual spraying (IRS).

Country	Thousands of households/ units sprayed with residual insecticide [§]						# persons per HH	Total # persons sprayed	Total population at risk	IRS coverage	Other coverage estimates
AFRO	1999	2000	2001	2002	2003	Mean					
Angola				4		4	5.1	20,560	13,052,181	0.16%	10% ¹³
Ethiopia			878	1106	1132	1039	4.8	4,984,870	44,135,069	11.3%	
Eritrea	125	40	77	56	87	77	4.8	369,600	3,808,530	10%	
Madagascar		214	60		111	128	4.9	629,119	15,781,440	4.0%	
Mauritius	0	0	0	1	0	1					
Mozambique	499	585	467	499		512	4.6	2,356,357	17,861,000	13%	9% ¹³
Rwanda		19	14	14	14	15	4.6	70,150	5,404,220	1.3%	
Senegal	69	42		93		68	9.0	609,762	9,393,000	6.5%	
South Africa	1000	1000	1000	1000	1000	1000	4.2	4,200,000	4,441,600	95%	80% ¹³
Swaziland		74	75	78	89	79	4.2*	332,632	317,400	100%	95% ¹³
Uganda		6	18	13	10	11	4.8	55,079	22,340,931	0.2%	
Zambia		31	32	32	61	39	5.2	203,922	10,542,348	1.9%	0% ¹³
Zimbabwe	916	845		978	546	821	4.2	3,449,125	6,378,000	54%	34% ¹³
EMRO											
Sudan	45	46	50	268	263	134	5.0*	672,000	27,991,678	2.4%	
Yemen			1	13	36	16	4.8	78,722	10,937,165	0.7%	
SEARO											
Bangladesh					4000	4000	5.2	20,800,000	133,575,239	16%	
Bhutan	26	33	32	35	39	33	4.4	144,595	767,106	19%	
Myanmar					2	2	4.8	10,752	43,465,388	0.02%	0.81% (SEARO)
Pakistan	1993: 1700 [#]	1994: 1000 [#]	1995: 750 [#]			1150	3.3	3,795,000	100,840,251	3.8%	
Sri Lanka					619	619	4.8	2,970,552	14,656,017	20%	
Thailand	250	238	225	301		253	4.8	1,216,758	59,408,728	2.0%	21% (RBM/SEAR/WPR/IC/WP99 report for 1996)
Vietnam	2874					2874	4.8	13,795,037	71,558,460	19%	

[§] Source: For African countries, the First progress report on implementation of the plan of action of the Abuja Declaration; for Yemen an EMRO report, for Bangladesh, Bhutan, Myanmar, Sri Lanka and Thailand a SEARO report, for Viet Nam a country report.

* In absence of DHS data, for Swaziland the average of South Africa and Zimbabwe; for Sudan the average across all sub-Saharan African countries; for Myanmar, Sri Lanka, Thailand, Viet Nam and Yemen the average of Bangladesh and Bhutan.

[#] Source: ¹⁴.

For SEARO and WPRO, country profiles for 9 out of the 20 malarious countries provided coverage estimates, usually as a proportion of the at-risk populations, but the underlying definition of 'coverage' was mostly unspecified, and might refer to the proportion of the (at risk) population that was the target of a malaria control programme including IRS, or a proportion of the at risk population that had actually recently been sprayed. SEARO and WPRO country profiles also gave an indication of non-negligible IRS coverage in 7 out of the 11 countries for which no specific coverage estimate was available, and similarly,

there was evidence for effective IRS interventions without a coverage estimate being available for several countries in AFRO and EMRO.

In order to still account for the impact of IRS and not overestimate malaria incidence in these countries, data on volumes of insecticides used for malaria vector control including IRS were converted to estimates of the number of households sprayed, using a specific application rate for each insecticide and assuming a mean sprayable area per house of 250m^2 ¹⁴ - *To be done once data have come forth from WHOPES (end Sept. 2004??).*

ANNEX 3. COUNTRY ENDEMICITY DISTRIBUTIONS: COMPARISON BETWEEN GLOBAL MAP AND COUNTRIES' OR REGION'S OWN ESTIMATE, FOR NON-AFRICAN COUNTRIES.

For non-African countries for which an estimate of the population at risk was available from the country or corresponding WHO region, this estimate was not always consistent with the proportion at risk according to the global map we used for the incidence estimations (background paper II). For some countries, the global map estimated larger population at risk; for some others, the country's or region's itself. The biggest discrepancies are shown in bold in Table A7.

Table A7.

Region COUNTRY	Lysenko/Oxford (Background paper II)						Region's or country's report					Source
	Any risk	Endemicity:					Any risk	Alternati	Hypo-	Meso-	Hyper-	
		Hypo-	Meso-	Hyper-	Holo-	Undefined						
EMRO Afghanistan	35%	3.9%	5.0%	27%	0%	21%	80%					EMRO country profile: 'over 57% in endemic areas' and endemicity class MARA: 98/100% but epidemic? EMRO country profile EMRO: no local transmission EMRO: no local transmission EMRO country profile MARA 1995, of which 81% epidemic MARA 1995 EMRO: Only Pv Vector Control in Yemen, 2000
EMRO Djibouti	88%	81%	7.5%	0%	0%	0%	99%					
EMRO Iran (Islamic Republic)	17%	1.4%	13%	2.0%	0%	2.4%	17%					
EMRO Iraq	24%	1.2%	6.8%	16%	0%	6.5%						
EMRO Morocco	2.0%	0%	2.0%	0%	0%	0%	0%					
EMRO Oman	1.0%	1.0%	0%	0%	0%	0%	0%					
EMRO Pakistan	78%	30%	42%	6.4%	0%	8.8%						
EMRO Saudi Arabia	14%	0%	13%	0.9%	0%	5.6%	23%					
EMRO Somalia	85%	43%	3.5%	39%	0%	0%	100%					
EMRO Sudan	87%	37%	39%	12%	0%	0.2%	99%					
EMRO Syrian Arab Republic	19%	0%	0%	19%	0%	1.1%						
EMRO Yemen	49%	1.1%	1.1%	47%	0%	15%	65%					
EURO Armenia	6%	0%	0%	6.1%	0%	46%						
EURO Azerbaijan	15%	0%	0.3%	15%	0%	3.7%						
EURO Georgia	4%	0%	0%	4.1%	0%	0.3%						
EURO Tajikistan	13%	0%	0%	13.3%	0%	7.2%						
EURO Turkey	12%	6.7%	3.4%	1.7%	0%	0%						
EURO Turkmenistan	5%	0%	0%	4.8%	0%	0%						
PAHO Argentina	6.0%	2.1%	3.8%	0%	0%	2.5%	7.8%	7%	1%	0%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high') PAHO 2002	
PAHO Belize	87%	83%	0%	3.7%	0%	0%	61%					
PAHO Bolivia	39%	4.8%	32%	2.3%	0%	0.3%	22%	16%	4%	2%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Brazil	12%	2.6%	6.9%	2.0%	0%	0%	11%	7%	3%	1%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Colombia	27%	2.1%	5.9%	19%	0%	6.4%	51%	42%	3%	6%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Costa Rica	19%	0%	0%	19%	0%	0%	34%	26%	7%	1%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Dominican Republic	94%	0%	93.7%	0%	0%	0%	100%	99%	1%	0%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Ecuador	56%	1.1%	55.1%	0%	0%	0.5%	63%	38%	8%	17%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO El Salvador	93%	0.0%	0.0%	93%	0%	0%	86%	51%	35%	0%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO French Guiana	5%	0.0%	4.6%	0.0%	0%	0%	98%	89%	0%	10%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Guatemala	51%	1.2%	0.1%	50%	0%	0%	42%	23%	15%	5%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Guyana	37%	0%	22%	15%	0%	0%	81%	61%	11%	8%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Haiti	94%	0%	94%	0%	0%	0%	100%	41%	59%	0%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Honduras	86%	0%	0%	86%	0%	0%	100%	37%	22%	41%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Mexico	19%	8.8%	4.1%	6.1%	0%	1.3%	54%	17%	18%	19%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Nicaragua	90%	0%	0%	90%	0%	1.2%	100%	94%	6%	0%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Panama	4%	0.2%	3.1%	0.7%	0%	0%	97%	82%	0%	15%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Paraguay	20%	0%	20%	0%	0%	0%	39%	14%	25%	0%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Peru	56%	8.6%	47%	0%	0%	1.2%	32%	16%	10%	6%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Suriname	7%	0.2%	6.1%	0.7%	0%	0%	11%	0%	5%	5%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
PAHO Venezuela	13%	2.3%	6.1%	4.7%	0%	2.2%	29%	27%	1%	2%	overall PAHO 2002; stratification PAHO 2003 ('low/moderate/high')	
SEARI Bangladesh	91%	23%	2.3%	66%	0%	0%	81%	88%				
SEARI Bhutan	2%	0%	0%	2.5%	0%	67.3%	21%	65%				
SEARI Democratic People's	1%	1.1%	0%	0%	0%	0%	87%	39%				
SEARI India	90%	22%	41%	27%	0%	1.8%	96%	95%				
SEARI Indonesia	71%	12%	25%	34%	0.1%	10.2%	71%	74%				
SEARI Myanmar	88%	23%	0%	65%	0%	0%	75%	72%				
SEARI Nepal	64%	0%	0%	64%	0%	7.3%	69%	72%				
SEARI Sri Lanka	77%	42%	0%	35%	0%	0.4%	55%	48%				
SEARI Thailand	97%	29%	45%	23%	0%	0.1%	68%	70%				
WPRC Cambodia	88%	20%	48%	20%	0%	0%	31%				WPRO	
WPRC China	51%	26%	19%	5.9%	0%	1%	2.8%				WPRO	
WPRC East Timor	87%	87%	0%	0%	0%	0%						
WPRC Lao PDR	92%	0%	28%	63%	0%	0%	74%				WPRO	
WPRC Malaysia	86%	5.6%	70%	11%	0%	0%	9%				WPRO	
WPRC Papua New Guinea	42%	0%	0%	24%	17.2%	23%	100%				WPRO	
WPRC Philippines	47%	38%	7.3%	1.8%	0%	30%	15%				WPRO	
WPRC Republic of Korea	1%	0.5%	0%	0%	0%	0%	4%				WPRO	
WPRC Solomon Islands		0%	0%	0%	0%	83%	99%				WPRO	
WPRC Vanuatu		0%	0%	0%	0%	81%	96%				WPRO	
WPRC Viet Nam	93%	24%	9%	60%	0%	0%	39%				WPRO	

ANNEX 4. CORRELATION OF INCIDENCE ESTIMATES FOR AFRO WITH HIS OUTCOMES

This Annex addressed the question whether, in Africa, estimated incidence bears any relationship to malaria indicators coming from the routine health information system (HIS). If there is a relationship between estimated incidence and a HIS indicator, this relationship could be used to update incidence estimates for future years, by applying the time trend observed in the HIS indicator. Updating incidence estimates using HIS data is attractive because the latter are available for most countries for most years, in contrast to data on other time-changing variables such as the coverage of malaria interventions.

As the HIS indicators we considered, besides, the case notification rate, the proportion of hospital admissions, of outpatient visits and of hospital deaths that are attributed to malaria (Table A8). The proportional outcomes are likely to be less prone to reporting bias than the absolute case notification rate. This is because underreporting generally affects not only malaria, but also other diseases, in a similar direction (reflecting general geographical and financial access to health care facilities). Therefore proportional distributions are less affected by changing reporting completeness than are absolute numbers.

Estimated overall incidence correlated positively with the proportion of hospital deaths attributed to malaria ($R^2 = 0.15$, $p=0.028$) and with the proportion of outpatient visits attributed to malaria ($R^2 = 0.23$, $p=0.009$) but not with the proportion of hospital admissions attributed to malaria (Table A9 and Figure A2). Similar but stronger correlations were found for the estimated incidence of *falciparum* malaria: against the proportion of hospital deaths attributed to malaria $R^2 = 0.16$, $p=0.024$, and against the proportion of outpatient visits attributed to malaria $R^2 = 0.27$, $p=0.005$. In contrast, no correlation was found between these proportional HIS indicators and the case notification rates.

These findings suggest that trends in the proportional malaria hospital mortality and malaria outpatient visits may be used to update the incidence estimates, and that these indicators are preferred above the case notification rate. The updating preferably occurs first on the estimated *falciparum* rate, for which the correlations are strongest; the overall incidence estimate can then be updated by backcalculation from the proportion of malaria cases attributed to *Plasmodium falciparum* (in HIS). The proportions of explained variation (R^2 's) are not so high (i.e. so close to 1) as to claim that the trend in these HIS outcomes would fully account for the true time trend in incidence. But updates in intervention coverage, proportion of urban population and in population at malaria risk may account for part of the remaining trend.

Table A8. HIS outcomes and estimated incidence in African countries.

	<i>HIS outcomes (average over the 3 most recent years with data available, for all ages combined)</i>				<i>Estimated incidence (pppa)</i>	
	<i>% of admissions due to malaria</i>	<i>% of hospital deaths due to malaria</i>	<i>% OPD due to malaria</i>	<i>Case notifications pppa</i>	<i>All species</i>	<i>Falciparum</i>
Angola	20	25	50	0.12	0.32	0.32
Benin	27	11	38	0.12	0.35	0.35
Botswana		2		0.02	0.02	0.02
Burkina Faso	34	39	34	0.10	0.37	0.37
Burundi	51	47		0.40	0.25	0.25
Cameroon	23	35		0.06	0.31	0.31
Chad	29	26	24	0.05	0.38	0.38
Comoros	37	34	40	0.01	0.28	0.26
Congo			18	0.00	0.36	0.36
Côte d'Ivoire	38	23	35	0.06	0.34	0.34
DRC		36	28	0.02	0.36	0.36
Eritrea	21	8	12	0.02	0.27	0.15
Ethiopia	33	26	23	0.01	0.17	0.09
Ghana	15	13	42	0.16	0.33	0.33
Guinea	30	15	31	0.10	0.37	0.37
Kenya	19	27	39	0.00	0.19	0.19
Madagascar		21		0.12	0.31	0.31
Malawi	31	24	36	0.28	0.36	0.36
Mali	42	43	37	0.01	0.37	0.37
Mauritania	22			0.08	0.29	0.29
Mozambique	60	30	40	0.15	0.31	0.31
Namibia	13	3	18	0.27	0.27	0.27
Nigeria	21	12	31	0.02	0.36	0.36
Rwanda	16	55	26	0.12	0.17	0.17
Sao Tome & Principe	69	48	57	0.30	0.21	0.20
Senegal	34	34	33	0.12	0.32	0.32
Sierra Leone	60	19	36	0.08	0.37	0.37
South Africa		0		0.00	0.00	0.00
Swaziland	6	3	2.3	0.02	0.02	0.02
Togo	36	32	42	0.09	0.36	0.36
Uganda	43	34	45	0.15	0.37	0.37
Tanzania	46	36	42	0.41	0.33	0.33
Zambia	49	33	38	0.20	0.33	0.33
Zimbabwe	18	5.3	12	0.07	0.07	0.07

OPD=outpatient clinic visits; HIS = health information system; pppa=per person per annum.

Table A9. Correlations (R^2 , or proportion of explained variation) between HIS outcomes and estimated malaria incidence in AFRO countries.

	<i>% of admissions due to malaria</i>	<i>% of hospital deaths due to malaria</i>	<i>% OPD due to malaria</i>	<i>Case notification rate</i>
Estimated all-species incidence	0.12	0.15	0.23**	0.03
Estimated <i>falciparum</i> incidence	0.12	0.16*	0.27**	0.05
Case notification rate	0.17	0.11	0.17	-
Degrees of freedom	27	30	26	32

**significant at $p=0.001$; * significant at $p=0.025$. OPD = outpatient clinic visits; HIS = health information system.

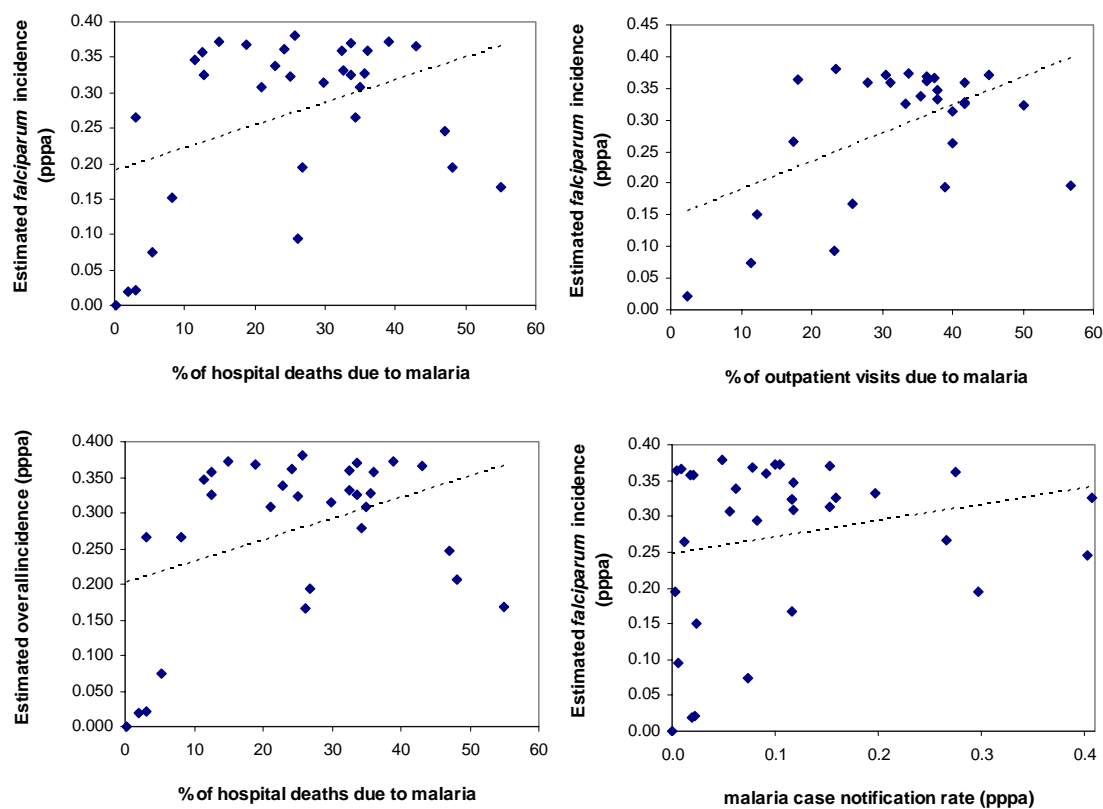


Figure A2. Correlations between HIS outcomes and estimated malaria incidence across 32 AFRO countries. For statistics see Table A9.

REFERENCES FOR THE ANNEXES

1. Hay SI, Guerra CA, Snow RW, 2004. Determination of country populations at malaria risk of different endemicities - report on agreement to perform work (APW) for WHO/Roll Back Malaria. Oxford: Oxford University, Dept. of Zoology, TALA Research Group.
2. Camargo LM, Ferreira MU, Krieger H, De Camargo EP, Da Silva LP, 1994. Unstable hypoendemic malaria in Rondonia (western Amazon region, Brazil): epidemic outbreaks and work-associated incidence in an agro-industrial rural settlement. *Am J Trop Med Hyg* 51: 16-25.
3. Camargo LM, Noronha E, Salcedo JM, Dutra AP, Krieger H, Pereira da Silva LH, Camargo EP, 1999. The epidemiology of malaria in Rondonia (Western Amazon region, Brazil): study of a riverine population. *Acta Trop* 72: 1-11.
4. Guthmann JP, Llanos-Cuentas A, Palacios A, Hall AJ, 2002. Environmental factors as determinants of malaria risk. A descriptive study on the northern coast of Peru. *Trop Med Int Health* 7: 518-25.
5. Luxemburger C, Thwai KL, White NJ, Webster HK, Kyle DE, Maelankirri L, Chongsuphajsiddhi T, Nosten F, 1996. The epidemiology of malaria in a Karen population on the western border of Thailand. *Trans R Soc Trop Med Hyg* 90: 105-11.
6. Nosten F, van Vugt M, Price R, Luxemburger C, Thway KL, Brockman A, McGready R, ter Kuile F, Looareesuwan S, White NJ, 2000. Effects of artesunate-mefloquine combination on incidence of Plasmodium falciparum malaria and mefloquine resistance in western Thailand: a prospective study. *Lancet* 356: 297-302.
7. Sharma SK, Tyagi PK, Padhan K, Adak T, Subbarao SK, 2004. Malarial morbidity in tribal communities living in the forest and plain ecotypes of Orissa, India. *Ann Trop Med Parasitol* 98: 459-68.
8. Valero MV, Amador LR, Galindo C, Figueroa J, Bello MS, Murillo LA, Mora AL, Patarroyo G, Rocha CL, Rojas M, et al., 1993. Vaccination with SPf66, a chemically synthesised vaccine, against Plasmodium falciparum malaria in Colombia. *Lancet* 341: 705-10.
9. International Institute for Population Sciences, DHS+ OMM, 2000. National Family Health Survey (NFHS-2), 1998-99: India. Mumbai: International Institute for Population Sciences (IIPS).
10. Snow RW, Craig M, Deichmann U, Marsh K, 1999. Estimating mortality, morbidity and disability due to malaria among Africa's non-pregnant population. *Bulletin of the World Health Organization* 77: 624-640.
11. ORC Macro - MEASURE DHS+, Demographic and Health Surveys (DHS): ORC Macro, Calverton, MD, USA.
12. UNICEF, 2001. Multiple Indicator Cluster Surveys (MICS-2) / End of Decade Assessment.
13. 2000. Multicountry evaluation. London: London School of Hygiene and Tropical Medicine.
14. Shah I, Rowland M, Mehmood P, Mujahid C, Raziq F, Hewitt S, Durrani N, 1997. Chloroquine resistance in Pakistan and the upsurge of falciparum malaria in Pakistani and Afghan refugee populations. *Ann Trop Med Parasitol* 91: 591-602.
15. Hay SI, Guerra CL, Tatem AJ, Noor AM, Snow RW, 2004. The global distribution and population at risk of malaria: past, present, and future. *Lancet Inf Dis* 4: 327-36.
16. Alves FP, Durlacher RR, Menezes MJ, Krieger H, Silva LH, Camargo EP, 2002. High prevalence of asymptomatic Plasmodium vivax and Plasmodium falciparum infections in native Amazonian populations. *Am J Trop Med Hyg* 66: 641-8.
17. al-Yaman F, Genton B, Anders R, Taraika J, Ginny M, Mellor S, Alpers MP, 1995. Assessment of the role of the humoral response to Plasmodium falciparum MSP2 compared to RESA and SPf66 in protecting Papua New Guinean children from clinical malaria. *Parasite Immunol* 17: 493-501.
18. Cardoso MA, Ferreira MU, Camargo LMA, Szarfanc SC, 1994. Anaemia, iron deficiency and malaria in a rural community in Brazilian amazon. *Europ J Clin Nutr* 48: 326-32.

19. Cox MJ, Kum DE, Tavul L, Narara A, Raiko A, Baisor M, Alpers MP, Medley GF, Day KP, 1994. Dynamics of malaria parasitaemia associated with febrile illness in children from a rural area of Madang, Papua New Guinea. *Trans R Soc Trop Med Hyg* 88: 191-7.
20. Das PK, Das LK, Parida SK, Patra KP, Jambulingam P, 1993. Lambda-cyhalothrin treated bed nets as an alternative method of malaria control in tribal villages of Koraput District, Orissa State, India. *Southeast Asian J Trop Med Public Health* 24: 513-21.
21. Fernando SD, Wickremasinghe AR, 2002. The clinical and epidemiological features of childhood malaria in a moderately endemic area of Sri Lanka. *Southeast Asian J Trop Med Public Health* 33: 671-7.
22. Ferreira MU, Kimura ES, Camargo LM, Alexandre CO, da Silva LH, Katzin AM, 1994. Antibody response against Plasmodium falciparum exoantigens and somatic antigens: a longitudinal survey in a rural community in Rondonia, western Brazilian Amazon. *Acta Trop* 57: 35-46.
23. Genton B, Al-Yaman F, Ginny M, Taraika J, Alpers MP, 1998. Relation of anthropometry to malaria morbidity and immunity in Papua New Guinean children. *Am J Clin Nutr* 68: 734-41.
24. Ghosh SK, Yadav RS, Das BS, Sharma VP, 1995. Influence of nutritional and haemoglobin status on malaria infection in children. *Indian J. Pediatr.* 62: 321-6.
25. Gunawardena DM, Wickremasinghe AR, Muthuwatta L, Weerasingha S, Rajakaruna J, Senanayaka T, Kotta PK, Attanayake N, Carter R, Mendis KN, 1998. Malaria risk factors in an endemic region of Sri Lanka, and the impact and cost implications of risk factor-based interventions. *Am J Trop Med Hyg* 58: 533-42.
26. Guthmann J-P, Hall AJ, Jaffar S, Palacios A, Lines J, Llanos-Cuentas A, 2001. Environmental risk factors for clinical malaria: a case-control study in the Grau region of Peru. *Trans.R.Soc.Trop.Med.Hyg.* 95: 577-83.
27. Jana-Kara BR, Jihullah WA, Shahi B, Dev V, Curtis CF, Sharma VP, 1995. Deltamethrin impregnated bednets against Anopheles minimus transmitted malaria in Assam, India. *J Trop Med Hyg* 98: 73-83.
28. Kamal S, Das SC, 2001. Epidemiological observations on malaria in some parts of Darrang District, Assam. *Indian J Malariol* 38: 25-31.
29. Kamolratanakul P, Dhanamun B, Lertmaharit S, Seublingwong T, Udomsangpetch R, Chirakalwasorn N, Thaithong S, 1992. Malaria in a rural area of eastern Thailand: baseline epidemiological studies at Bo Thong. *Southeast Asian J Trop Med Public Health* 23: 783-7.
30. Kamolratanakul P, Dhanamun B, Lertmaharit S, Seublingwong T, Udomsangpetch R, Thaithong S, 1994. Epidemiological studies of malaria at Pong Nam Ron, eastern Thailand. *Southeast Asian J Trop Med Public Health* 25: 425-9.
31. Kamol-Ratanakul P, Prasittisuk C, 1992. The effectiveness of permethrin-impregnated bed nets against malaria for migrant workers in eastern Thailand. *Am J Trop Med Hyg* 47: 305-9.
32. Luo D, Lu D, Yao R, Li P, Huo X, Li A, Wen L, Ge C, Zhang S, Huo H, et al., 1994. Alphamethrin-impregnated bed nets for malaria and mosquito control in China. *Trans R Soc Trop Med Hyg* 88: 625-8.
33. Luxemburger C, Perea WA, Delmas G, Pruja C, Pecoul B, Moren A, 1994. Permethrin-impregnated bed nets for the prevention of malaria in schoolchildren on the Thai-Burmese border. *Trans R Soc Trop Med Hyg* 88: 155-9.
34. Maitland K, Williams TN, Peto TE, Day KP, Clegg JB, Weatherall DJ, Bowden DK, 1997. Absence of malaria-specific mortality in children in an area of hyperendemic malaria. *Trans R Soc Trop Med Hyg* 91: 562-6.
35. Maitland K, Williams TN, Bennett S, Newbold CI, Peto TE, Viji J, Timothy R, Clegg JB, Weatherall DJ, Bowden DK, 1996. The interaction between Plasmodium falciparum and P. vivax in children on Espiritu Santo island, Vanuatu. *Trans R Soc Trop Med Hyg* 90: 614-20.

36. Mukhopadhyay AK, Karmakar P, Hati AK, Dey P, 1997. Recent epidemiological status of malaria in Calcutta municipal corporation area, West Bengal. *Indian Journal of Malariology* 34: 188-196.
37. Nosten F, Luxemburger C, Kyle DE, Ballou WR, Wittes J, Wah E, Chongsuphajaisiddhi T, Gordon DM, White NJ, Sadoff JC, Heppner DG, 1996. Randomised double-blind placebo-controlled trial of SPf66 malaria vaccine in children in northwestern Thailand. Shoklo SPf66 Malaria Vaccine Trial Group [see comments]. *Lancet* 348: 701-7.
38. Noya O, Gabaldon Berti Y, Alarcon de Noya B, Borges R, Zerpa N, Urbacz JD, Madonna A, Garrido E, Jimenez MA, Borges RE, et al., 1994. A population-based clinical trial with the SPf66 synthetic *Plasmodium falciparum* malaria vaccine in Venezuela. *J Infect Dis* 170: 396-402.
39. Prasad K, 1999. Indoor residual spray versus treated mosquito nets using deltamethrin to control malaria- a community randomized trial in rural Surat, India.
40. Richards FO, Jr., Klein RE, Flores RZ, Weller S, Gatica M, Zeissig R, Sexton J, 1993. Permethrin-impregnated bed nets for malaria control in northern Guatemala: epidemiologic impact and community acceptance. *Am J Trop Med Hyg* 49: 410-8.
41. Rowland M, Mahmood P, Iqbal J, Carneiro I, Chavasse D, 2000. Indoor residual spraying with alphacypermethrin controls malaria in Pakistan: a community-randomized trial. *Trop Med Int Health* 5: 472-81.
42. Roper MH, Torres RS, Goicochea CG, Andersen EM, Guarda JS, Calampa C, Hightower AW, Magill AJ, 2000. The epidemiology of malaria in an epidemic area of the Peruvian Amazon. *Am J Trop Med Hyg* 62: 247-56.
43. Sahu SS, Jambulingam P, Vijayakumar T, Subramanian S, Kalyanasundaram M, 2003. Impact of alphacypermethrin treated bed nets on malaria in villages of Malkangiri district, Orissa, India. *Acta Trop* 89: 55-66.
44. Shankar A, Genton B, Semba RD, Baisor M, Paino J, Tamja S, Adiguma T, Wu L, Rare L, Tielsch JM, Alpers MP, West Jr KP, 1999. Effect of vitamin A supplementation on morbidity due to *Plasmodium falciparum* in young children in Papua New Guinea: a randomised trial. *Lancet* 354: 201-7.
45. Sharma SN, Subbarao SK, Choudhury DS, Pandey KC, 1993. Role of *An. culicifacies* and *An. stephensi* in malaria transmission in urban Delhi. *Indian J Malariol* 30: 155-68.
46. Valero MV, Amador R, Aponte JJ, Narvaez A, Galindo C, Silva Y, Rosas J, Guzman F, Patarroyo ME, 1996. Evaluation of SPf66 malaria vaccine during a 22-month follow-up field trial in the Pacific coast of Colombia. *Vaccine* 14: 1466-70.
47. Williams TN, Maitland K, Bennett S, Ganczakowski M, Peto TE, Newbold CI, Bowden DK, Weatherall DJ, Clegg JB, 1996. High incidence of malaria in alpha-thalassaemic children. *Nature* 383: 522-5.
48. Wu N, Qin L, Liao G, Zhou W, Geng W, Shi Y, Tan Y, Zhao K, 1993. Field evaluation of bednets impregnated with deltamethrin for malaria control. *Southeast Asian J Trop Med Public Health* 24: 664-71.
49. Yadav RS, Sampath TR, Sharma VP, Adak T, Ghosh SK, 1998. Evaluation of lambda-cyhalothrin-impregnated bednets in a malaria endemic area of India. Part 3. Effects on malaria incidence and clinical measures. *J Am Mosq Control Assoc* 14: 444-50.
50. Rowland M, Bouma M, Ducornez D, Durrani N, Rozendaal J, Schapira A, Sondorp E, 1996. Pyrethroid-impregnated bed nets for personal protection against malaria for Afghan refugees. *Trans R Soc Trop Med Hyg* 90: 357-61.
51. Rowland M, Durrani N, Hewitt S, Mohammed N, Bouma M, Carneiro I, Rozendaal J, Schapira A, 1999. Permethrin-treated chaddars and top-sheets: appropriate technology for protection against malaria in Afghanistan and other complex emergencies. *Trans R Soc Trop Med Hyg* 93: 465-72.
52. Rowland M, Downey G, Rab A, Freeman T, Mohammad N, Rehman H, Durrani N, Reyburn H, Curtis C, Lines J, Fayaz M, 2004. DEET mosquito repellent provides personal protection against

- malaria: a household randomized trial in an Afghan refugee camp in Pakistan. *Trop Med Int Health* 9: 335-42.
53. Shankar AH, Genton B, Baisor M, Paino J, Tamja S, Adiguma T, Wu L, Rare L, Bannon D, Tielsch JM, West KP, Jr., Alpers MP, 2000. The influence of zinc supplementation on morbidity due to Plasmodium falciparum: a randomized trial in preschool children in Papua New Guinea. *Am J Trop Med Hyg* 62: 663-9.

Figure 1. Locations of research studies included in analyses of malaria incidence rates outside Africa

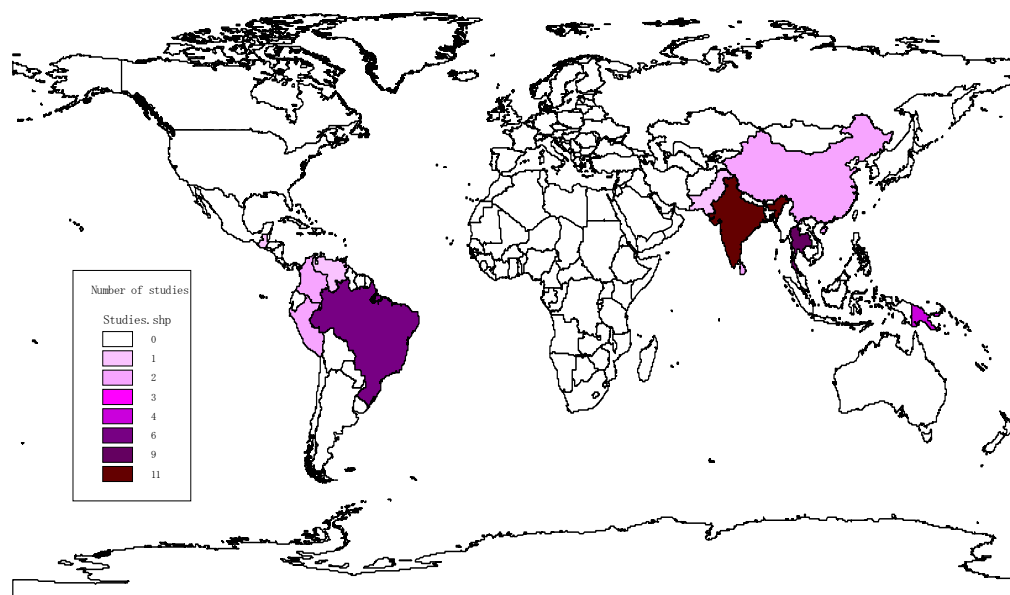


Table A1. Summary of longitudinal community-based studies of malaria incidence in non-African populations. Unless indicated, not subject to malaria prevention by ITN or IRS.

Reference	Site	Residence	Study population	Time	Endemicity as described by authors	Endemicity on Lysenko map ¹	% <i>falciparum</i>	Age group	Type of surveillance ²	Incidence (pppa)		
										Total	<i>Falciparum</i>	<i>Vivax</i>
Alves et al. ¹⁶	Amazon, Brazil	rural		Sept 98-Sept 99	High endemic but seasonal	mesoendemic	50%	all-age	Weekly	0.33	0.16	0.15
Al-Yaman et al. ¹⁷	Wosera, PNG	rural		Oct 92-93	High perennial, peak Nov-March	holoendemic	78%	0.5-15y*	Weekly	0.77	0.60	
Camargo et al. ³	Rondonia (W. Amazon), BRAZIL	rural		June 94 - May 95		mesoendemic		all-age*	3-weekly	0.29	0.11	0.19
Camargo et al. ²	Rondonia (W. Amazon), BRAZIL	rural		Jan 91-Jan 92	Unstable, hypoendemic	mesoendemic	40%	all-age*	Bi-weekly	0.97	0.39	0.58
Cardoso et al. ¹⁸	Urupa, Rondonia (W. Amazon), BRAZIL	rural		Feb 91-Jan 92	Unstable transmission	hypoendemic [§]	40%	all-age ⁺	Weekly	0.83	0.33	0.5
Cox et al. ¹⁹	Madang, PNG	rural		Oct 90-Sept 91	High perennial	holoendemic	56%	2-15y	Weekly	0.37	0.29	0.09
Das et al. ²⁰	Koraput, Orissa, INDIA	rural	C arm ITN trial ITN arm	Sept 89-June 91	High perennial, peak Oct-Nov	hyperendemic	90%	all-age	Fortnightly	0.62	0.37	
da Silva Nunes, PhD thesis	Western Brazilian amazon	rural		May 04-Jul 04	Unstable, hypoendemic	mesoendemic	36%	all-age*	Active of unknown frequency + passive	0.90	0.32	0.58

¹ Endemicity according to the global Lysenko map (ref. 15. Hay SI, Guerra CL, Tatem AJ, Noor AM, Snow RW, 2004. The global distribution and population at risk of malaria: past, present, and future. *Lancet Inf Dis* 4: 327-36. and Background paper II) was assumed in regression analyses, except for studies which themselves stated a higher endemicity; the latter are indicated as [§].

² Active case detection of the specified frequency, unless indicated.

⁺ One episode of *Plasmodium falciparum* was excluded from January 1991 and therefore the study duration was 12 months

Reference	Site	Residence	Study population	Time	Endemicity as described by authors	Endemicity on Lysenko map ¹	% falciparum	Age group	Type of surveillance ²	Incidence (pppa)		
										Total	Falciparum	Vivax
Fernando et al. ²¹	Moneragala District, SRI LANKA	rural		Jan 98- Dec 99	Moderate and seasonal	hypoendemic ^s	32%	0-12y	'Activated passive case detection' [no further information given]	0.86	0.27	0.59
Ferreira et al. ²²	Rondolia, Brazilian amazon	rural		Jan 91 - Jan 92	Unstable, hypoendemic	mesoendemic	58%	all-age	Active in surveys Jan+July+Jan. + passive	0.96	0.56	0.40
Genton et al. ²³	Wosera, PNG	rural		1991-2?	High perennial, peak Nov-March	holoendemic	61%	10-120m	Weekly	1.00	0.74	0.26
Ghosh et al. ²⁴	Orissa, INDIA	rural		1991-2	High	hyperendemic	80%	1-9y	Weekly	0.40	0.32	0.08
Gunawardena et al. ²⁵	Kataragama, SW SRI LANKA	rural		Jan 92 - Jul 93	EIR 0.5-1, endemic but unstable	hypoendemic ^s		all-age	Passive (90% of detected cases) + 2-3 monthly surveys	0.60		
Guthmann et al. ²⁶	Northern coast of Peru	rural		May 96- June 97	High	mesoendemic _s	45%	all-age*	Weekly	0.04	0.02	0.02
Jana-Kara et al. ²⁷	Sonapur, Assam, INDIA	rural	C arm ITN trial ITN arm	June 87 - Nov 89	Most malarious of India - high	hyperendemic	72%	all-age	Weekly	0.67	0.44	
Kamal et al. ²⁸	Darrang District, Assam (INDIA)	rural		April 94- March 95	High perennial	hyperendemic	92%	all-age	Monthly	0.04	0.04	0.00
Kamolratanakul et al. ²⁹	Bo Thong district, THAILAND	rural		89-90	Low-to-moderate stable, seasonal	mesoendemic	58%	all-age	Monthly	0.054*		
Kamolratanakul et al. ³⁰	Pong Nam Ron district, E. THAILAND	rural		89-90	High seasonal	mesoendemic _s	70%	all-age	Weekly	0.054		
Kamol-Ratanakul et al. ³¹	E. rural THAILAND	rural	Migrant workers (80% M)	Nov 87- July 88	High	hyperendemic	59%	adults (80% migrants)	Weekly	0.22		

Reference	Site	Residence	Study population	Time	Endemicity as described by authors	Endemicity on Lysenko map ¹	% falciparum	Age group	Type of surveillance ²	Incidence (pppa)		
										Total	Falciparum	Vivax
**												
Luo et al. ³²	Henan province, CHINA	rural	C arm ITN trial	May 90- Oct 90	Moderate	hypoendemic ^s		0-10y	Twice weekly	0.04 [±]		0.04
Luxemburger et al. ⁵	Shoklo camp, NW THAILAND	rural		Nov 91- Nov 92	Low unstable (EIR 1)	hyperendemic	40%	all-age*	Weekly + 2-monthly surveys	0.80	0.35	0.45
Luxemburger et al. ⁵	Shoklo camp, W. THAILAND	rural		Nov 91 - Nov 92	Low unstable (EIR 1)	hyperendemic	40%	4-15y	Daily	1.00		
Luxemburger et al. ³³	Shoklo camp, NW THAILAND	rural	C arm ITN trial ITN arm	Aug 90 - Feb 91	Low unstable (EIR 1)	hyperendemic	56% 49%	4-15y	Monthly and passive	1.30 0.87	0.73 0.42	0.57 0.45
Maitland et al. ³⁴	Espiritu Santo, Vanuatu, MELANESIA	rural		92-4	Hyperendemic		63%	<10y	Weekly	1.90	1.20	0.70
Maitland et al. ³⁵	Espiritu Santo, Vanuatu, MELANESIA	rural		92-4	Hyperendemic		56%	<10y	Weekly	1.40	0.77	0.61
Muckhopadhyay et al. ³⁶	Calcutta, India	urban		Jan 95- July 96	Endemic	hyperendemic	29%	all-age	Monthly	0.13	0.04	0.09
Nosten et al. ³⁷	Shoklo camp, NW THAILAND	rural		Oct 93 - July 95	Low unstable (EIR 1)	hyperendemic	40%	4-15y	Daily	0.95	0.38	0.57
Nosten et al. ⁶	Shoklo camp, NW THAILAND	rural	baseline Treatment programme F-up	92 97	Low unstable (EIR 1)	hyperendemic	41% 30%	all-age*	Weekly	0.93 0.42	0.38 0.13	0.55 0.29
Noya et al. ³⁸	Las Majadas, S. VENEZUELA	rural	C arm of vaccine trial	<94	Seasonal, mean API 0.1→ high	mesoendemic ^s	25%	all-age	10-daily and passive	0.29	0.06	0.23

Reference	Site	Residence	Study population	Time	Endemicity as described by authors	Endemicity on Lysenko map ¹	% falciparum	Age group	Type of surveillance ²	Incidence (pppa)		
										Total	Falciparum	Vivax
Prasad ³⁹	Surat, INDIA	rural	C arm	May 96 - May 99	Perennial and relatively high transmission	mesoendemic _s	6%	all-age	Bi-weekly	0.05	0.003	0.047
			IRS/ITN programme				4%			0.03	0.001	0.033
			IRS arm				3%			0.02	0.001	0.022
			ITN arm									
Richards et al. ⁴⁰	Los Amates, Izabal, N. GUATEMALA	rural	C arm ITN trial	Aug 90- Oct 91	Hypoendemic	hyperendemic	16%	all-age	Fortnightly	0.27		
			ITN arm				2%			0.14		
			ITN arm				25%			0.40	0.10	0.30
Rowland et al. ⁴¹	Sheikhupura district, Punjab province, PAKISTAN	rural	C arm IRS trial	May 97 - April 98	Seasonal, API 0.050	mesoendemic _s	48%	all-age*	Fortnightly	0.04	0.02	0.02
			IRS arm				18%			0.01	0.00	0.01
Roper et al. ⁴²	Amazon, PERU	rural		Aug 97 - July 98	Perennial i.e. High	mesoendemic _s	17%	all-age	Active in surveys Feb.+April and passive	0.99		
Sahu et al. ⁴³	Orissa, INDIA	rural	C arm ITN trial	May 98 - April-00	Highly endemic	mesoendemic _s	80%	all-age	Fortnightly	0.16	0.13	0.03
			ITN arm				86%			0.06	0.05	0.006
Shankar et al. ⁴⁴	N.Wosera, PNG	rural	Vitamin A trial	July 95 - Aug 96	High perennial (EIR 100)	holoendemic	61%	6-60m	Weekly	1.7		
Sharma et al. ⁴⁵	Delhi, India	urban		June 84 - May 86	Epidemic zone?	mesoendemic	52%	all-age	Weekly	0.01	0.01	0.01
Sharma et al. ⁷	Orissa, INDIA	rural	Forest communities	Jan 01- Dec 01	hyperendemic	hyperendemic	86%	all-age*	Weekly + passive	0.35	0.30	0.05
			Plain communities		mesoendemic	mesoendemic	65%			0.06	0.04	0.02
Valero et al. ⁸	La Tola, COLOMBIA	rural	C arm of vaccine trial	90-1	Perennial seasonal, API 130/1000	Mesoendemic _s	84%	all-age*	Monthly	0.43	0.36	0.07

Reference	Site	Residence	Study population	Time	Endemicity as described by authors	Endemicity on Lysenko map ¹	% falciparum	Age group	Type of surveillance ²	Incidence (pppa)		
										Total	Falciparum	Vivax
Valero et al. ⁴⁶	Tumaco, COLOMBIA	rural	C arm of (effective) vaccine trial	Jan 92-94	Endemic, API 0.207 for <i>P.f</i> and 0.12 for <i>P.v</i>	hypoendemic ^s	52%	all-age	Monthly + passive	0.16	0.08	0.08
Williams et al. ⁴⁷	Espiritu Santo, Vanuatu	rural		Jan 92 - Nov 93	Perennial and seasonal			0-9y	Weekly	1.47	0.80	0.70
Wu-N et al. ⁴⁸	Napo county, Guangxi Zhuang region, CHINA	rural	C arm IRS/ITN programme IRS arm ITN arm	Apr 90 - 92	Hypoendemic, suppressed with periodic resurgences	mesoendemic	56%	all-age	1 parasitological survey + fever cases presenting to CHW	0.00 0.00 0.00		
Yadav et al. ⁴⁹	forested hamlets near Rourkela, Orissa, INDIA	rural	C arm ITN programme ITN arm	89-93 90-3	High	hyperendemic	84%	2-9y	Weekly	0.31 0.13	0.26 0.11	0.05 0.02
Passive case detection studies (at present not included in regression analyses):												
Rowland et al. ⁵⁰	Baghicha & Kachan, Mardan district, PAKISTAN	rural	C arm ITN trial	July-Dec 91	Low-moderate seasonal (PR adults May-June 13%)	hyperendemic	35%	all-age*	Passive case detection	0.86	0.30	0.56
Rowland et al. ⁵¹	Adizai refugee settlement near Peshawar, Pakistan (North West frontier province)	rural	C arm of a treated chaddars and top sheets	July - Dec 96	seasonal, and unstable	hyperendemic	54%	all-age*	Passive case detection	0.92	0.50	0.42
Rowland et al. ⁵²	Adizai refugee settlement near Peshawar, Pakistan (North West frontier province)	rural	C arm of a repellent trial	Aug 99 - Feb 00	seasonal, and unstable	hyperendemic	43%	all-age*	Passive case detection	0.41	0.18	0.23
Shankar et al. ⁵³	N.Wosera, PNG	rural	Zinc trial	Nov 95 - Sept 96	Perennial (EIR 100)	holoendemic	61%	6-60m	Passive case detection	1.3	0.80	

*Studies from which an age-breakdown on malaria incidence was available.

** The majority of this adult population being migrant workers with no immunity, this study population was categorized as all-age, because a similar incidence rate would be expected in non-immune children.

± For analyses, a year-round rate of 0.02 pppa was used, based on 0.04 pppa during 5 months of transmission and assuming zero incidence during the 7 remaining non-transmission months of the year.

§ For these studies, for the regression analysis categorized endemicity according to the study's own definition (instead of according to the global Lysenko map,¹⁵ and Background paper II), in order to account for probable selection of study site in the locally most endemic place.

CHW = community health worker. C arm = comparison arm of a trial; PR = malaria parasite prevalence rate; EIR = entomological inoculation rate (per year).